Report to the Colville National Forest on the Results of the South Deep Watershed Fire History Research

R. Schellhaas, A. E. Camp,
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ABSTRACT

We reconstructed the fire history for the portion of the South Deep watershed managed by the Colville National Forest. This fire history encompasses the period between 1683 and 1910, and is based on 773 individual fire scars from 168 cross sections and 215 remnant tree cores. We stratified the landscape by aspect into smaller, more homogeneous sampling units. We also separated this fire history into two periods. The pre-settlement era (prior to 1860) documents fire frequency and extent prior to the land clearing, livestock grazing, and road building influences of Eurosettlement. The settlement era (1860 - 1910) reflects fire regimes during the period of active settlement but excludes those years following the onset of active fire suppression. We did, however, document the dates and extent of fires that occurred in the watershed after 1910.

During the pre-settlement era (pre 1860) fires were less frequent and larger than during Eurosettlement (1860-1910). For the watershed as a whole, mean fire frequency prior to settlement was 5.9 years; during settlement MFFI dropped to 2.5 years. For individual aspect polygons, pre-settlement MFFIs ranged between 11 and 39.4 years. During settlement, that range decreased to between 4.5 and 25.5 years. Point-based estimates of fire frequency calculated at 23 locations ranged between 15.7 and 46.7 years. Pre-settlement fire size averaged 520 acres, decreasing to 337 acres during the settlement era. Estimated fire size was highly variable, with a range of 28 to nearly 15,000 acres. Jaccard Similarity Indices computed for adjacent polygons separated by either a valley bottom or ridgeline indicate that fire events within aspect polygons were

not statistically independent; fires frequently burned from one polygon across a topographic boundary into an adjacent polygon.

The variability inherent within the historical fire regime of the South Deep watershed suggests historical vegetation patterns that were correspondingly variable. Point-based estimates of fire frequency show some areas experienced fires 2 to 3 times more frequently than did other areas. Area-based estimates of fire frequency suggest this range of variability may be even greater. We located one stand that probably has not burned since it established following a fire in 1751. Overall, however, our data indicate fires occurred more frequently and were less severe than previously was believed for northeastern Washington's mesic mixed conifer forests.

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1. INTRODUCTION

Managing densely stocked stands of small-diameter trees within a framework of sustaining ecosystems and communities is a complex problem faced by land managers on the Colville National Forest and throughout the Inland West. Many dense, small-diameter stands dominated by lodgepole pine, Douglas-fir, and associated species originated following severe fires in the 1920s and 1930s. Fires during this period were often accidentally or deliberately ignited, and it was not known if the fires - or the forest vegetation patterns that developed in their wake - had historical analogs.

Landscape patterns and underlying ecological processes are the template under which a regional biota evolved; maintaining these patterns and processes is one approach to conserving biological diversity (sensu Hunter 1991). Landscape patterns that deviate greatly from historical patterns may fulfill certain management objectives, but there is concern that one of the tradeoffs may be a greater risk of insect and disease outbreaks or catastrophic wildfire. Additionally, such landscapes may not provide adequate habitat for the full complement of regional biota.

Fire was one of the primary disturbances that created and maintained landscape vegetation patterns in the inland West prior to settlement by people of European descent. In the dry ponderosa pine and Douglas-fir forests of the Inland West, many fire history studies have documented a pre-settlement disturbance regime characterized by frequent, low severity fires (Cooper 1960,

Barrett 1988, Agee 1993, Covington and Moore 1994, Everett et al. 2000). This type of fire regime created and maintained a landscape dominated by open parklike stands of ponderosa pine with an herbaceous understory (Weaver 1943, Gruell et al. 1982). Successionally advanced stands composed of multiple canopy layers and species not tolerant of fire were found where topography, soils, or a combination of environmental conditions and vegetation attributes allowed formation of “fire refugia” - areas less frequently affected by the dominant fire regime (Camp 1995, Camp et al. 1997).

In contrast to the high frequency, low severity fire regime of the ponderosa pine / Douglas-fir forest types are the moderate frequency, mixed severity regimes characteristic of more mesic mixed conifer forests in the Inland West (Agee 1990, 1993). Mixed severity fire regimes created more complex landscape vegetation patterns. Longer intervals between successive fires allowed forests to develop farther along successional trajectories. Greater variability in fire frequency and severity coupled with more mesic conditions supported a greater mix of species in both the overstories and understories of these forest types. Parameters of fire regime variability in mixed severity fire regimes are not well-documented in the Inland West.

Dense stands of small-diameter lodgepole pine and other conifer species within forest landscapes on the Colville National Forest are causing concern over their potential for initiating outbreaks of mountain pine beetle as well as fueling catastrophic wildfires. Although they originated following high severity (stand replacing) fires that occurred during the 1920s and 1930s, many of these stands

are within landscapes historically dominated by mixed severity fire regimes. At the request of the Colville National Forest and in response to a Congressionally-mandated research program (CReating OPportunities, or CROP) focused on management of dense, small-diameter stands of lodgepole pine and associated species, we initiated a study and collected data during the1999 field season to derive a fire history of the South Deep watershed. This report summarizes our reconstruction of the historical fire history of the portions of the South Deep watershed within the boundary of the Colville National Forest.

2. METHODOLOGY

2.1 Site Description

The South Deep watershed consists of 50,192 acres between the Columbia and Pend Oreille rivers in northeastern Washington, about 15 miles northeast of Colville. The watershed is within the Selkirk Mountains and is within the Okanogan Cool/Moist Forest subregion of the Northern Rocky Mountain-Steppe-Coniferous Forest-Alpine Meadow Province of the Northern Glaciated Mountains Ecological Reporting Unit (USDA/USDI 1997). Elevations range from 1,948 feet at the mouth to 5,777 foot Mount Rogers. The watershed was settled during the first decade of the 20th century although native groups may have occupied it at various times prior to Eurosettlement (Ayers et al. 1979).

The South Deep watershed is ecologically and biophysically similar to other watersheds in the Okanogan Highlands Cool/Moist Forest subregion (Hessburg, et al. In press). Roughly half the watershed is within the Douglas-fir Potential Vegetation Zone, 40% within the western hemlock / western redcedar PVZ, and the remaining area within the grand fir and subalpine fir PVZs. Even though the South Deep watershed is within a Cool/Moist Forest subregion, much of the Potential Vegetation is characterized as warm/dry (Figure 1). Detailed descriptions of the biophysical setting and human history of the watershed can be found in the South Deep Creek Watershed Analysis document (Colville National Forest 1999).

2.2 Field Methods for Master Chronology and Fire History

Data for this fire history were collected on the 29,740 acres of the watershed within the boundary of the Colville National Forest. This portion of the watershed was stratified by aspect into 21 polygons ranging in size from 309 to 2,086 acres (Table 1, Figure 2). Each polygon was intensively searched for evidence of past fires, including fire-scarred trees, snags, logs, and stumps. On living fire-scarred trees and snags, wedges containing the fire scars were cut using the method described by Arno and Sneck (1977). Samples from logs and stumps were sectioned to ensure collection of the maximum number of fire scar events. In fifteen of the polygons, we found remnant trees, snags, and logs containing fire scars. In the remaining 6 polygons, scarred remnant material was seemingly destroyed by the last fire, the date of which was inferred by coring trees that regenerated in the aftermath of that event.

In polygons where direct evidence of past fires was scarce, locations of remnant trees (those remaining following a fire) were identified and mapped on historical and current aerial photographs. These trees were then located in the field and increment cores obtained to infer and extend the fire history record through cohort analysis (sensu Heinselmann 1973, Oliver and Larson 1996). Locations of fire scarred samples were geo-referenced and entered into a GIS database for subsequent mapping of fire locations and extent. In all, 168 fire-scarred samples were found and an additional 215 increment cores were collected.

Accuracy in determining the exact year in which a fire occurred depends on developing a master chronology, or time series of tree-ring widths in which the climate signal is maximized. Tree growth on dry, rocky outcrops in the South Deep watershed is limited by available soil moisture, which changes in response to annual precipitation. Trees growing on these harsh sites have narrow annual growth rings in dry years and wide rings in wet years. Fifteen of these climatically sensitive trees were cored to develop a master chronology for dating fire-scars.

2.3 Laboratory Preparation and Analysis

Increment cores from climatically-sensitive trees were used to develop a skeleton plot of signature wet and dry years following procedures described by Stokes and Smiley (1968). The skeleton plot was used to construct a 400 year master chronology. Signature years and recognizable patterns of years were used to cross-date fire scars on each sample and assign the correct calendar year to each fire scar (Madany et al 1982, Dietrich and Swetnam 1984, Brown and Swetnam 1994, Grissino-Mayer 1995a). Cross-dating was facilitated by developing a list of marker years (Yamaguchi 1991) that could be readily identified on many of the fire scar sections.

Wedges from fire-scarred trees and snags were stored in a cool, dry location. Each wedge was sanded with a succession of sandpapers, ending with either a 320 or 400 grit. Many of the sections cut from western larch snags and logs were partially rotten and required extensive gluing and re-construction before they could be sanded and fire scars dated. Fire scars from live trees and

dead wood were dated by visually comparing ring patterns with those in the master chronology.

Once each fire scar was assigned a date, these data were analyzed using the FHX2 software package (Grissino-Mayer 1995b). Fire intervals were computed using the composite, Weibull median, and point-frequency methods. Fire chronologies were assembled for each aspect polygon and for the watershed. Data were further stratified into two time periods, pre-settlement (prior to 1860) and pre-suppression era settlement (1860-1910).

Fire extent maps were completed for individual fire years using data from the geo-referenced locations of fire-scarred samples and tree cores (after Agee et al. 1986). Tree cores located within or near the established fire perimeter that exhibited aberrant ring patterns were used to reinforce fire boundary locations. Historical fire boundaries were developed using criteria similar to those used by Hemstrom and Franklin (1982). As did they, we made the following assumptions:

1. A fire starting within the general area of where the samples were collected would spread until encountering a topographic or fuel barrier.
2. Fire spread was in an uphill direction.
3. Fire boundaries were conservatively estimated; perimeters were not extended beyond the evidence of fire scar or cohort data except by rules 1 and 2.

Two methods were used to map fire extent. The first was based primarily on fire scars, supported by pith dates from scar sample cross sections and

remnant tree cores that corresponded with established fire scar data (the more conservative method, shown in red on the fire year maps in the Appendix). The other method relied on fire scar dates from samples as well as pith dates and ring patterns from cores that matched known fire years (the extended method, shown in yellow on the fire year maps in Appendix A). Reported fire sizes reflect the more conservative estimate.

3. FIRE HISTORY TERMINOLOGY AND CONCEPTS

3.1 Fire Frequency

Researchers report results of fire history studies using specialized terminology. Without an understanding of fire history terms and concepts, it can be difficult to interpret the results of a study, compare results from different studies, or develop management options based on study results.

Fire interval (FI), fire-free interval (FFI), and fire return interval (FRI) are three synonymous terms that refer to the number of years between two successive fire events in a given area. The arithmetic average (mean) of all fire intervals in a given area over a given time period is referred to as the mean fire return interval (MFRI) or mean fire frequency interval (MFFI). This metric is the one that has commonly been used to characterize fire regimes and is based on an underlying assumption, not necessarily correct, that fire return intervals are distributed normally. Grissino-Mayer (1995a) suggests that the Weibull median fire frequency interval (WMFFI) is a more accurate metric for characterizing fire regimes when fire frequency distributions are skewed (the distribution curve is not normal (bell-shaped), but has one tail longer than the other). For this study, we have chosen to follow the terminology used in the fire history analysis software developed by Grissino-Mayer (1995b). We report both MFFI and WMFFI when data were sufficient to calculate the latter. Where data were not sufficient to calculate the WMFFI statistic, we report only the MFFI.

3.2 Point vs Area Estimations of Fire Frequency

Another concept necessary to fully comprehend and compare reconstructed fire histories is the difference between point-based and area-based MFFIs (or WMFFIs). The following definitions of point and area frequencies were taken from Agee (1993). A point frequency is the mean fire interval at a single point (an individual scarred tree) on the landscape. In practice, point frequencies are usually expanded to include data from several proximate scarred trees because a single tree may not always record every fire. Agee (pers. comm.) recommends sampling 3 to 5 scarred trees in close proximity (within < 3 acres) to derive an accurate estimate of fire frequency at an individual location. An area frequency represents the mean interval between fires that burned some portion of, but not necessarily the entire, sampled area. Successive fires within an area may overlap somewhat, entirely, or not at all. Point-based estimates of MFFIs are generally larger (longer periods between successive fires) than those derived from area estimates (Kilgore and Taylor 1979).

Ecological (fire effects) implications can be confounded by reporting an MFFI but neglecting to mention if the estimate is based on data from a single point or from across a large landscape. Knowing the size of the area on which the estimated MFFI is based is critical; as the size of a sampled area increases, MFFIs generally decrease. In fact, there are existing studies that report MFFIs of less than 2 years (Kilgore and Tayor 1979, Dieterich 1980). These estimates are based on fire scars collected across very large landscapes. Estimates of fire frequency taken from samples collected across large landscapes are generally not suitable for inferring ecological processes based on the effects of recurring

fires. Actual fire frequency at any specific point on the large landscapes studied and reported on is much greater than 2 years. Area frequencies reflect the incidence of fire somewhere, but usually not everywhere, within the sampled area. Variability around the MFFI within an area becomes more pronounced as the sampled area increases in size or heterogeneity, with some areas experiencing fire frequencies much higher or lower than the mean. In contrast, point-based estimates of fire frequency, especially when corroborated by multiple scar samples taken from several proximate trees, provide specific information about the periodicity of recurring fires - and the effects of those fires - at a known place on the landscape.

As might be expected for a mixed-severity fire regime, fire scar data within the South Deep watershed was sparsely and somewhat unevenly distributed. In some areas, we found sufficient scarred material with which to construct point-based estimates of fire history. In addition to this, we constructed area-based estimates within aspect polygons which were smaller and more homogeneous than the South Deep watershed as a whole.

4. RESULTS

The earliest fire we were able to document within the South Deep watershed occurred in 1399; we also documented individual fires from the fifteenth and sixteenth centuries. Although we were able to document some very old fire events, the number of surviving scar samples from the 14^{th} and 15^{th} centuries was too small to reliably infer fire frequencies or sizes for that time period.

The number and quality of the fire scar samples we collected enabled us to reconstruct the fire history of much of the sampled portion of the South Deep watershed back to 1683. Our fire history analyses do not include fires that occurred after 1910, although several fires burned portions of the South Deep watershed after that date. We chose 1910 as the cutoff date for our fire history analysis because at about that time fires began to be actively suppressed. We believe that including fires that occurred after 1910 would introduce bias. We found scar evidence for the occurrence of fires in the watershed into the mid-1980s.. In 5 of the 6 polygons in which no scarred material could be found, it appears that one or more stand replacing fires occurred sometime after 1910, obliterating all fire scar evidence within those polygons. We do, however, include maps of post-1910 fires that show locations and sizes of fires that occurred through 1924.

For the entire sampled portion of the South Deep watershed, the MFFI for the pre-settlement period (1683 - 1860) was 5.9 years and the WMFFI was 5.1 years. Remember from the above discussion in concepts that these numbers reflect only that, on average, there was a fire somewhere within the sampled area (>29,000 acres) every 5 to 6 years. For the period of active settlement (1861 - 1910), the MFFI and WMFFI were 2.5 and 2.1 years respectively. The positively skewed distribution of the data suggest that the WMFFI statistic more accurately reflects fire return intervals for the South Deep watershed. Positive skewing is to be expected for mixed severity fire regimes (Grissino-Meyer, pers. comm.).

The estimated number of acres burned within the sampled portion of the watershed each year since 1683 are shown in Figure 3 and the total estimated area burned each decade is shown in Figure 4. Not unexpectedly for a relatively small area within a mixed-severity fire regime, year by year and even decade by decade variation in the number of acres burned is high. The Coefficient of Variation (CV) for the number of acres burned per year within the watershed is 1.36; the CV for acres burned per decade is 0.98.

Of more use from a management perspective, fire histories within each aspect polygon were independently reconstructed and results tabulated (Table 2). The table includes both the MFFI and WMFFI statistics whenever possible; however, several aspect polygons contained fewer than the required number of scar samples necessary for calculating WMFFI. The following comparisons are made using only the MFFI metric. Pre-settlement MFFIs ranged from 11.0 years

in Polygon 3 (Paradise Valley South) to a high of 39.4 years in Polygon 9 (Meadow Creek South). The percent of a polygon burned over on average ranged from a low of 26% in Polygon 15 (Clinton Creek South) to a high of 99% in Polygon 6 (Ione Hill South). Average (mean) percent of the polygon burned was generally > 50% with the only exceptions being Polygons 7 and 15. Average (mean) fire size within an individual polygon was generally less than 500 acres; however, most fires burned across polygon boundaries and into adjacent polygons.

Figure 5 shows the 23 locations for which we were able to derive point-based estimates of MFFI. The point-based estimates were, as expected, generally longer than area-based estimates, ranging from 15.7 to 46.6 years (Table 3). The time periods for which these point-based estimates of MFFI are based vary among points, reflecting differences in the quality and availability of scar samples at each point.

During the settlement period, MFFIs ranged from between 4.5 years in Polygon 14 (Rabbit Mountain South) to 25.5 years in Polygon 10 (Aladdin Mountain North); in the former instance, MFFI sharply decreased while in the latter there was a slight increase. The mean percentage of the polygon that burned increased from the pre-settlement period in 3 polygons but decreased in the remaining polygons. Mean fire size within an individual polygon during the settlement period decreased to 337 acres, but most fires burned across polygon boundaries during this period as well.

Estimates of actual fire size range from a 28 acre fire (in 1905) to one that burned nearly 15,000 acres (roughly half of the sampled portion of the watershed) in 1831. The series of maps in Appendix A show locations and estimated size of fires for each of the years in which we documented fire activity within the South Deep watershed. Fire sizes were conservatively estimated and typically exclude private lands within the watershed. Actual fire sizes were probably somewhat larger than our estimates.

To ascertain if topographic features historically served as firebreaks, we computed Jaccard Similarity Indices (JSI) between pairs of adjacent polygons separated by either a valley bottom or a ridgeline. A higher Jaccard Similarity Index indicates that the polygons being compared shared similar fire events and thus the topographic feature separating the polygons was not effective in stopping spread of fire between the polygons. We found the highest indices for pairs of north and south slopes separated by a ridge, indicating that fires frequently crossed this topographical barrier. None of the JSIs were low enough to suggest that ridges or valley bottoms were consistently effective at halting fire spread across the South Deep landscape.

We found that fire frequency varied considerably around the mean. This variability occurred, as might be expected, between different portions of the landscape. Less expected was the variability that occurred at a single point on the landscape. From some of the point-based estimates of fire frequency we found large differences in the minimum and maximum intervals between successive fires (Table 3). For example, at point # 23, the variability around the

MFFI of 29.5 years was a minimum interval of 5 years and a maximum interval of range of 83 years. Other points, notably # 8 and # 17 had differences between minimum and maximum fire intervals that were nearly as great.

5. DISCUSSION

In landscapes influenced by mixed severity fire regimes, reconstructing accurate fire histories that extend back more than several centuries is difficult because each successive fire destroys some evidence of previous fires. That our history extends back 3 centuries indicates that most fires were not severe enough to consume the entire woody biomass over large portions of the watershed. Exceptions to this are the six polygons in which we found little to no remains of the previous stand. Polygon 21 (Polley's Cabin) contains a stand that established after a fire in 1751 that obliterated past fire evidence within that polygon. There has been no evidence of fire within that stand since 1751. The five remaining polygons were so severely burned during the late teens or 1920s that no record remains with which to reconstruct past fire history. It is not possible to ascertain if these polygons represent an area that historically burned less frequently but with greater severity than surrounding stands; use of Forest Service vegetation mapping databases and vegetation classification plots (sensu Williams 1995) might prove useful for determining if biophysical environments in these polygons differ substantially from the rest of the sampled watershed.

Fire size does not imply 100% mortality within the fire boundary. A mixed severity fire regime will typically experience moderate severity fires (20-70% basal area killed) with occasional low (<20% basal area killed) or high (> 70% basal area killed) severity fires (Agee 1990, 1993). Residual basal area following a fire would be concentrated in larger trees of fire resistant species such as

western larch, ponderosa pine, and larger Douglas-fir. Most small trees, especially those species not tolerant of fires would be killed unless they were protected within a vegetation patch entirely missed by the fire. Vegetation patches repeatedly left unburned by successive fires may be thought of as fire refugia (Camp 1995, Camp et al. 1997). As described above, we identified what appears to be a fire refugia in the area of Polley's cabin, at the confluence of two perennial streams. Overstory trees in this stand include western larch, western hemlock, and western redcedar between the ages of 203 and 248 years. This stand originated following a severe fire in 1751 that obliterated any evidence of previous fires. The location of the Polley's Cabin stand between two forks of Polley's Creek has apparently buffered it from subsequent fires, including the extensive fire of 1831.

Within each aspect polygon we found pith ages of scarred samples to vary considerably, strongly suggesting that most polygons historically contained multiple even-aged stands with different dates of origin and/or stands containing multiple cohorts. Our data are not sufficient to permit analysis of the pattern of remnant trees following particular fires nor the number and frequency of different age cohorts within individual stands. In all probability there was a wide range of historical structures, compositions, and ages arising from the variability in fire size, the temporal pattern of fires across the landscape, the range of fire return intervals, and the complexity of fire severity characteristic of mixed severity fire regimes (see maps of fires by date in the Appendix). Malanson (1987) hypothesizes that structural and compositional diversity is greatest for ecosystems impacted by mixed severity disturbance regimes.

One of the findings of Hessburg (1999 unpublished regionalization data released to the Colville National Forest) was that the current number of large trees has significantly decreased from recent historical conditions (1930s - 1950s recorded from old aerial photographs) within the South Deep watershed and other watersheds sharing similar biophysical characteristics. In the oldest aerial photographs, large trees were documented as a component of nearly all stand types (development phases), including those regenerating following severe fires. These remnant large trees were targeted for timber harvest and are now conspicuously absent from the landscape. Large trees of fire-tolerant species frequently survive successive fires (as evidenced by the multiple-scarred remains of trees (frequently stumps) used to reconstruct this fire history) and were scattered throughout the watershed. Few such trees remain in the South Deep watershed today, and they are particularly lacking in young stands that historically contained some remnant trees from older cohorts.

The small number of fires that appear in the southwestern part of the watershed may be an artifact of one or more severe fires that burned between 1926 and 1929. There is not enough cohort data from cored trees to verify the dates or extent of fires in this portion of the watershed. Characterizing the fire regime for this area might best be accomplished by comparing it with areas having similar biophysical characteristics for which past fire history is known.

The existence of a historical mixed severity fire regime within the South Deep watershed is possibly best evidenced through the range of diameters at

which trees sustained their initial fire scar (Figure 6). For the South Deep watershed as a whole, mean diameter at initial scar formation (6.5 inches / 16.5 cm) is wider compared to what is typically found in dry eastern Cascades landscapes where historical fires were frequent but of low severity (Everett et al. 2000). Mean diameter at initial scarring within South Deep is also greater that what has been described for other areas characterized by low severity regimes, suggesting that most of the trees smaller than that diameter were probably killed (Arno 1988, Everett et al. 2000). Among aspect polygons there is considerable variability in the mean and range of diameters at which trees were initially scarred. At the high end are polygons 11a and 15, with mean diameters at initial scar formation of between 10 and 15 inches, with a wide range; at the low end are polygons 2-5 and 13 where diameters at initial scar formation were < 5 inches, with a much narrower range. These differences suggest fire severity may have been greater in polygons 11a and 15 as compared with polygons 2-5 and 13. Polygon 15 in particular has a lower bound on the range of diameters at initial scarring that is greater than the upper bounds of that range found in polygons 2,4, and 5. The relatively small sample on which this analysis is based precludes testing for the statistical significance of this finding. The occurrence of trees of fire- tolerant species that attained larger diameters prior to initial scarring as well as the longer fire free intervals found in reconstructing the fire history provide evidence that the gaps in fire return intervals allowed substantial buildup of understory vegetation (trees and shrubs). When fire again visited these areas, the buildup of fuels supported more intense fires that killed smaller trees and breeched the protective outer bark to scar larger trees.

One of the most striking findings of this study was a 78 year period between 1752 and 1830 when fires in the South Deep watershed were noticeably reduced. During this period, the average acres burned per year dropped to 98.5; prior to and following this period, average acres burned per year was 1430 and 1423 acres. Efforts to correlate this period of low fire activity with regional climate data have thus far been inconclusive (D. Petersen pers. comm.). Not surprisingly, the largest fire recorded in this study occurred in 1831. This fire, at 14,876 acres, was nearly twice the size of the next largest fire we documented (8,059 acres in 1866). An untested hypothesis is that the 78 year fire hiatus reflects initial contacts between native populations and European fur traders. As natives moved toward a barter economy with the trappers or were decimated by diseases for which they had no immunity, this period may have experienced fewer aboriginal ignitions. That fires ultimately did return to this landscape may reflect the beginning of accidental or purposeful ignitions by early settlers, although there is no record of non-native settlement within the South Deep watershed until about 1900 (Bohm and Holstein 1983).

6. CONCLUSION

Results from this study do not support an oft-repeated belief that, except in dry ponderosa pine / Douglas-fir forests, fires were a relatively infrequent disturbance event that allowed mixed conifer forests to develop far along successional trajectories and approach the potential vegetation assemblages possible under regional climate conditions. The sampled portion of the South Deep watershed historically was influenced by a mixed severity fire regime. A strong positive skewness in the distribution of fire return intervals and the presence of old scar samples suggest that, for this particular mixed severity regime, many of the fires were of low severity. Low MFFIs suggest that the South Deep watershed, despite the current presence of fire intolerant species such as subalpine fir and western redcedar, historically was dominated by species more tolerant of fires such as western larch, ponderosa pine, and large Douglas-fir.

What differentiates the South Deep watershed from areas historically influenced by low severity / high frequency fire regimes is a more mesic biophysical environment that allowed more species to exist and more rapid forest development along successional trajectories. Greater variability in both fire severity and frequency would have been expressed on the landscape as a more complex mosaic of stand compositions in various stages of development. Some areas burned frequently and would have been dominated by fire tolerant species. There may have been fire refugia, such as the one near Polley's Cabin, where species not able to tolerate frequent fires survived, apparently for several

centuries. Tying together stands of all ages and compositions were large remnant trees whose thick bark enabled them to survive the low, moderate, and sometimes even severe fires that burned within the watershed.

TABLES

Table 1: Acreage and aspect of polygons

Polygon #	Polygon Name (Location)	Aspect	Acres
1	Little Smackout	S	417
2	Little Smackout	N	816
3	Paradise Valley	S	528
4	Paradise Valley	N	642
5	Ione Hill	W	787
6	Ione Hill	S	423
7	North Fork Byers	S	366
8	Byers Creek	S	771
9	Meadow Creek	S	776
10	Aladdin Mtn.	N	2086
11a	Aladdin Mtn.	W	577
11b	Aladdin Mtn.	S	1083
12	Rocky Creek	S	643
13	West Fork Rocky Creek	S	544
14	Rabbit Mtn.	S	304
15	Clinton Creek	S	465
16	Polley Creek	S	81
17	North Fork Rogers Creek	S	274
18	Kenny Creek	S	145
19	Huckleberry Mtn.	S	185
20	Rocky Creek	W	239
21	Polley’s Cabin	N	151

Table 2: Summary of fire intervals, mean number of acres burned within the polygon, and mean percentage of the polygon burned.

	Pre 1860			1860-1910		
Polygon	**MFFI / WMFFI**	**Area burned**	**% burned**	**MFFI / WMFFI**	**Area burned**	**% burned**
1 Smackout S	20.4 / 22.9	345	83	16.0 / nc	412	99
2 Smackout N	17.5 / nc	764	93	10.0 / 8.7	402	49
3 Paradise S	11.0 / nc	299	57	11.7 / 9.2	208	39
4 Paradise N	31.0 / 24.4	588	93	19.5 / nc	221	35
5 Ione Hill W	30.3 / 27.8	667	85	13.0 / 11.6	406	50
6 Ione Hill S	25.6 / 23.8	417	99	12.0 / 11.4	315	74
7 NF Byers S	15.0 / nc	146	40	12.0 / 10.8	206	57
8 Byers Cr. S	27.3 / 22.9	469	61	15.0 / nc	440	57
9 Meadow Cr. S	39.4 / 37.7	506	65	nc	nc	nc
10 Aladdin Mt. N	17.5 / nc	1489	71	25.5 / nc	561	27
11a Aladdin Mt. W	25.4 / 17.6	379	66	14.0 / nc	314	54
11b Aladdin Mt. S	35.0 / nc	985	91	25.0 / nc	552	51
12 Rocky Cr. S	32.8 / 30.2	391	61	17.0 / nc	227	36
13 WF Rocky Cr. S	20.0 / 15.5	nc	nc	nc	nc	nc
14 Rabbit Mt. S	22.3 / 14.7	238	77	4.5 / 4.3	175	55
15 Clinton Cr. S	14.7 / 14.9	122	26	14.0 / nc	282	61

MFFI = mean fire frequency interval; WMFFI = Weibull median fire frequency interval; nc = not calculated, available data were insufficient for calculating this statistic

Table 3: Point-based estimates of fire frequency for 23 sites within the South Deep watershed.

Point #	Period	MFFI	SD	Max FI	Min FI
1	1842-1904	20.7	8.3	30	14
2	1704-1904	25.0	11.0	41	11
3	1781-1904	20.5	8.3	31	11
4	1765-1906	15.7	6.4	26	6
5	1828-1896	22.7	11.0	35	11
6	1831-1892	20.3	8.1	26	11
7	1831-1866	17.7	9.2	24	11
8	1683-1900	31.0	23.7	80	9
9	1831-1909	19.5	4.5	26	16
10	1683-1894	35.2	22.5	73	12
11	1595-1909	39.3	19.9	73	15
12	1683-1885	28.9	18.0	55	12
13	1718-1900	26.0	19.1	55	6
14	1726-1866	46.7	29.3	80	25
15	1831-1894	31.5	4.9	35	28
16	1595-1847	42.0	21.6	77	16
17	1717-1891	29.0	25.3	80	13
18	1831-1891	20.0	4.6	25	16
19	1831-1922	45.5	14.8	56	35
20	1831-1916	28.3	12.7	42	17
21	1831-1891	20.0	18.7	40	3
22	1804-1886	16.4	4.8	24	11
23	1726-1903	29.5	30.9	83	5

MFFI = mean fire frequency interval, SD = standard deviation, FI = fire interval

FIGURES

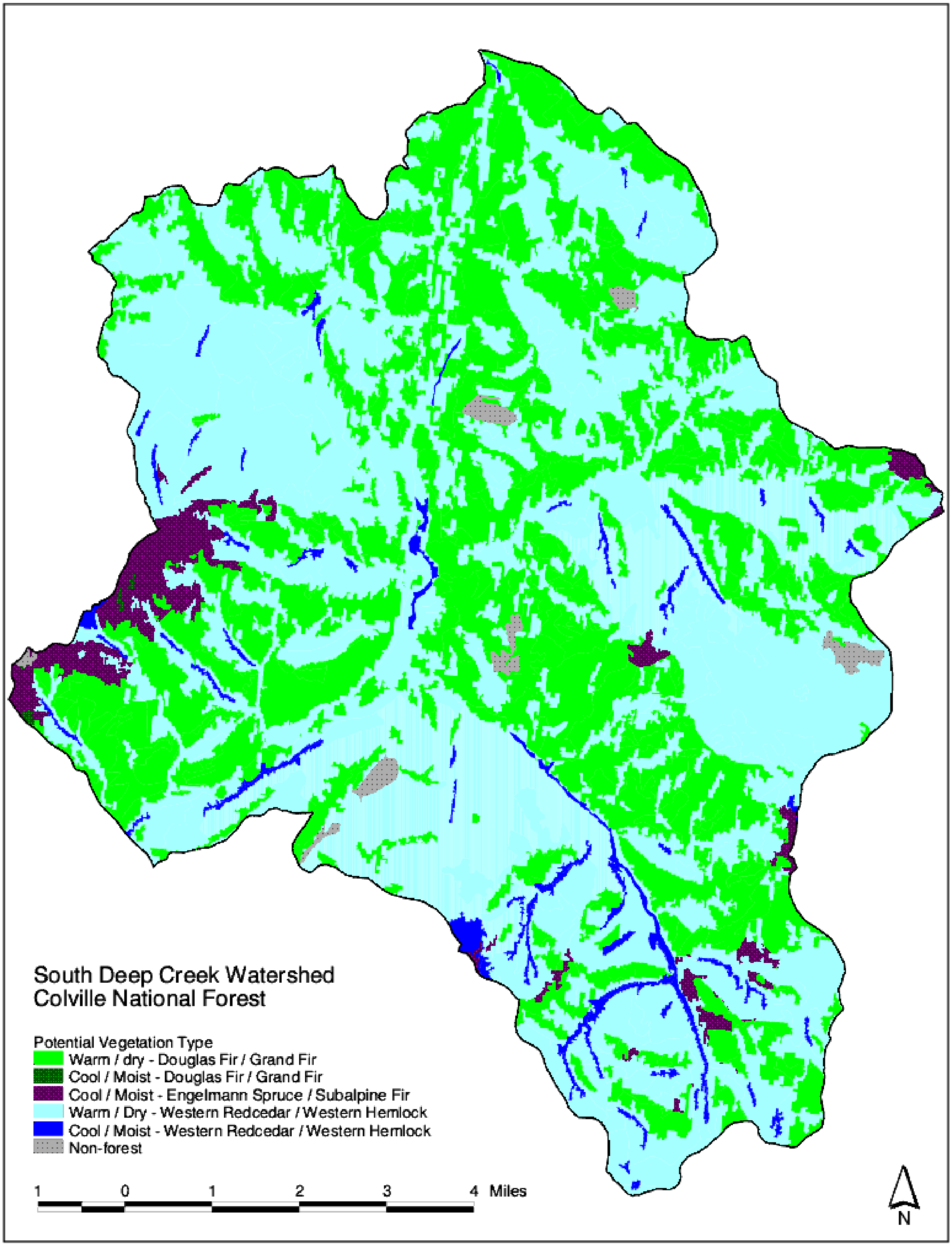

Fig. 1. Map of Potential Vegetation of the South Deep watershed.

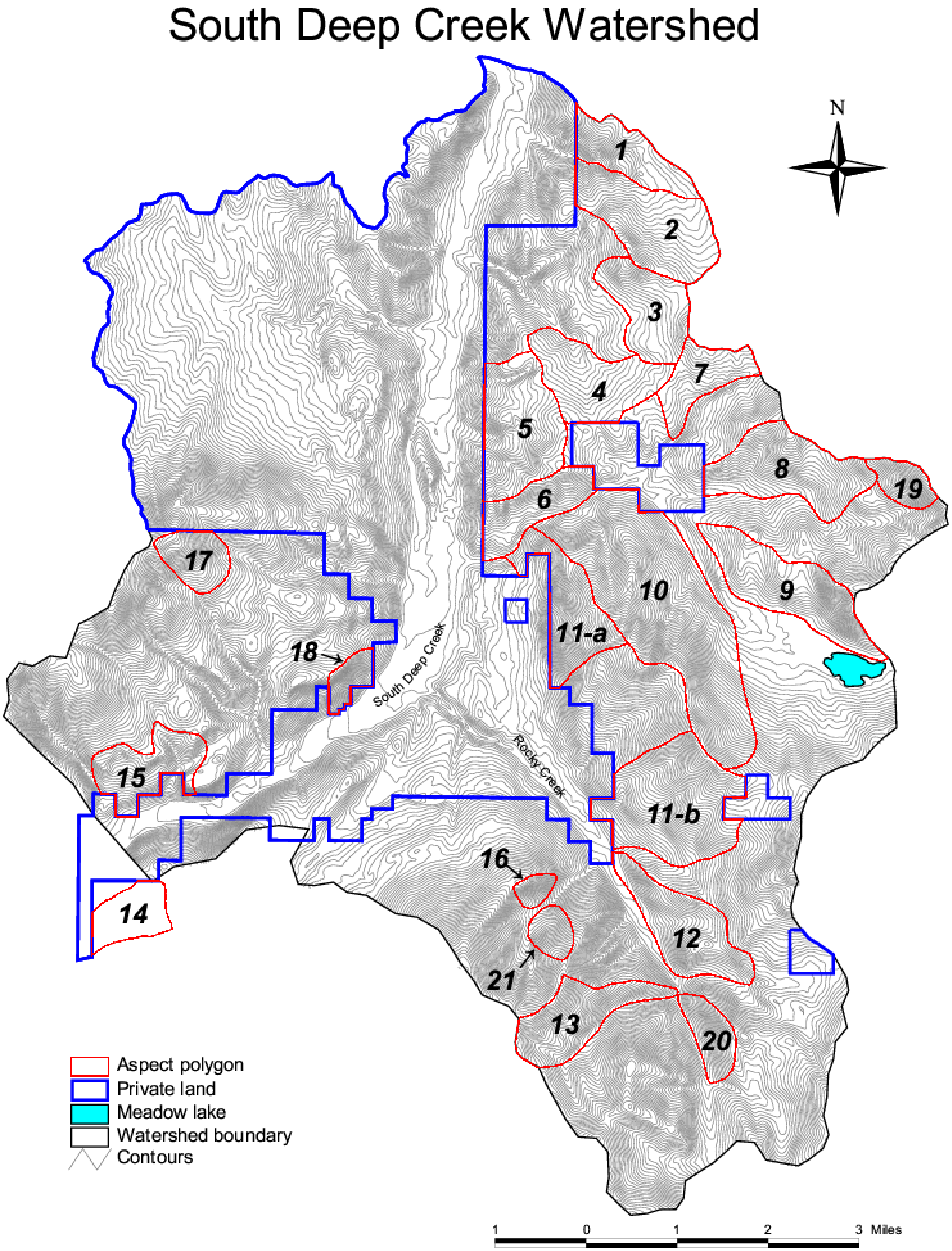

Fig. 2. Map of the South Deep watershed showing aspect polygons and Colville National Forest boundaries.

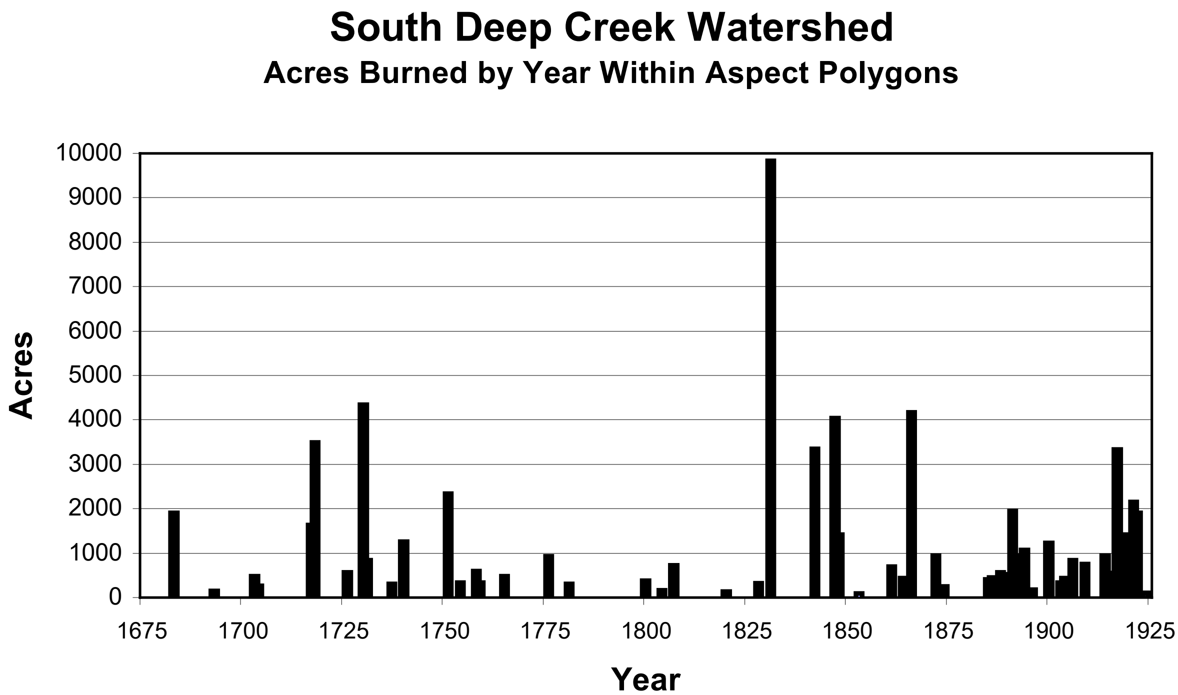

Fig. 3. Graph showing the estimated acreage burned within the sampled portion of the South Deep Creek watershed by year.

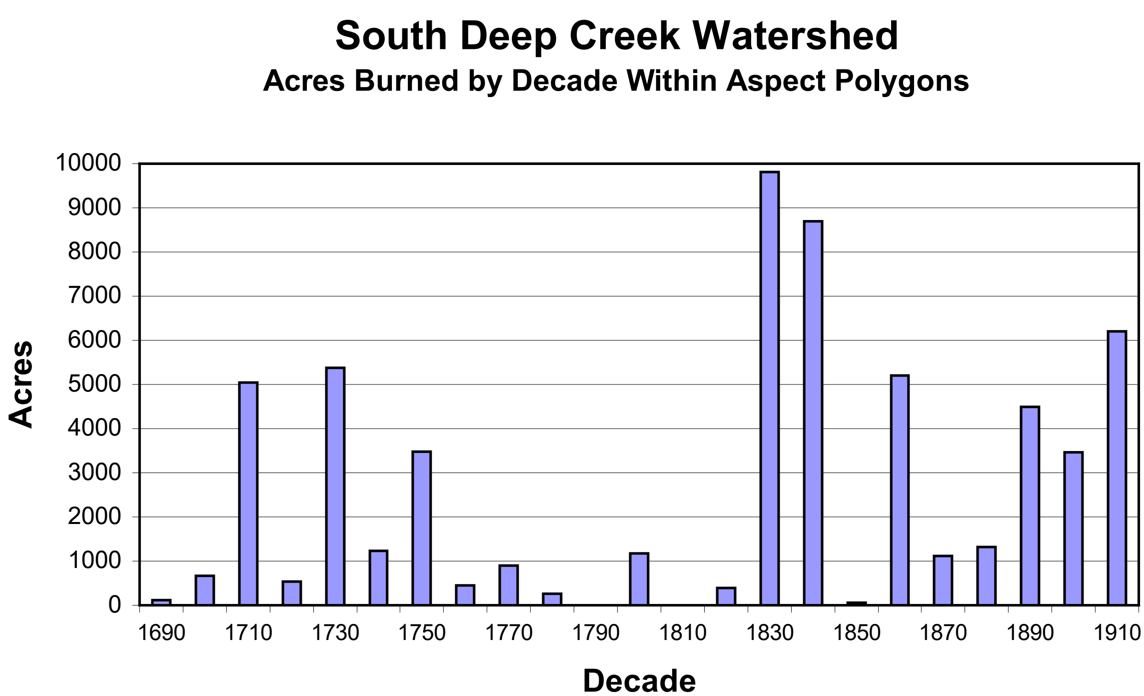

Fig. 4. Graph showing the estimated acreage burned within the sampled portion of the South Deep watershed by decade.

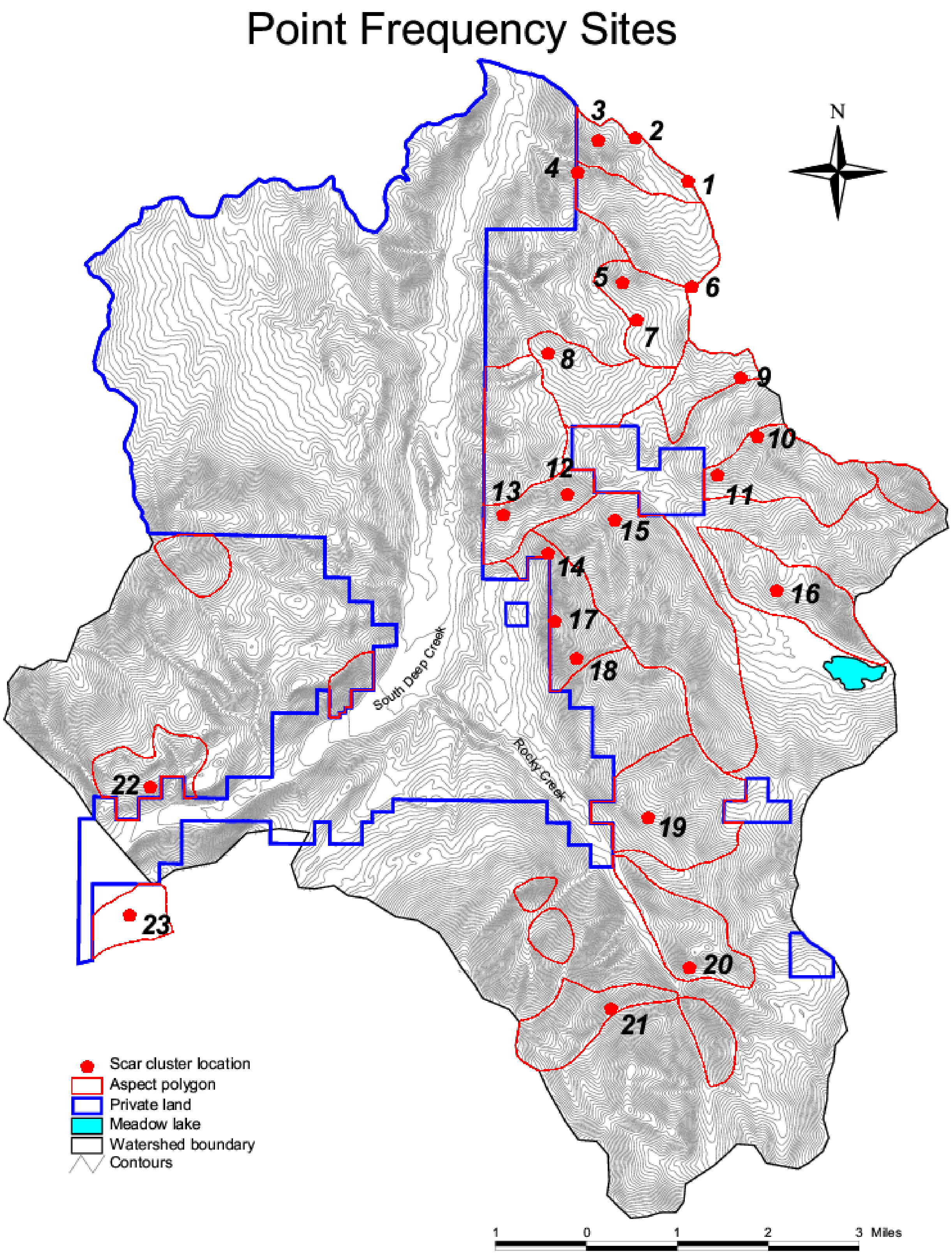

Fig. 5. Map showing the locations of point-based fire return intervals.

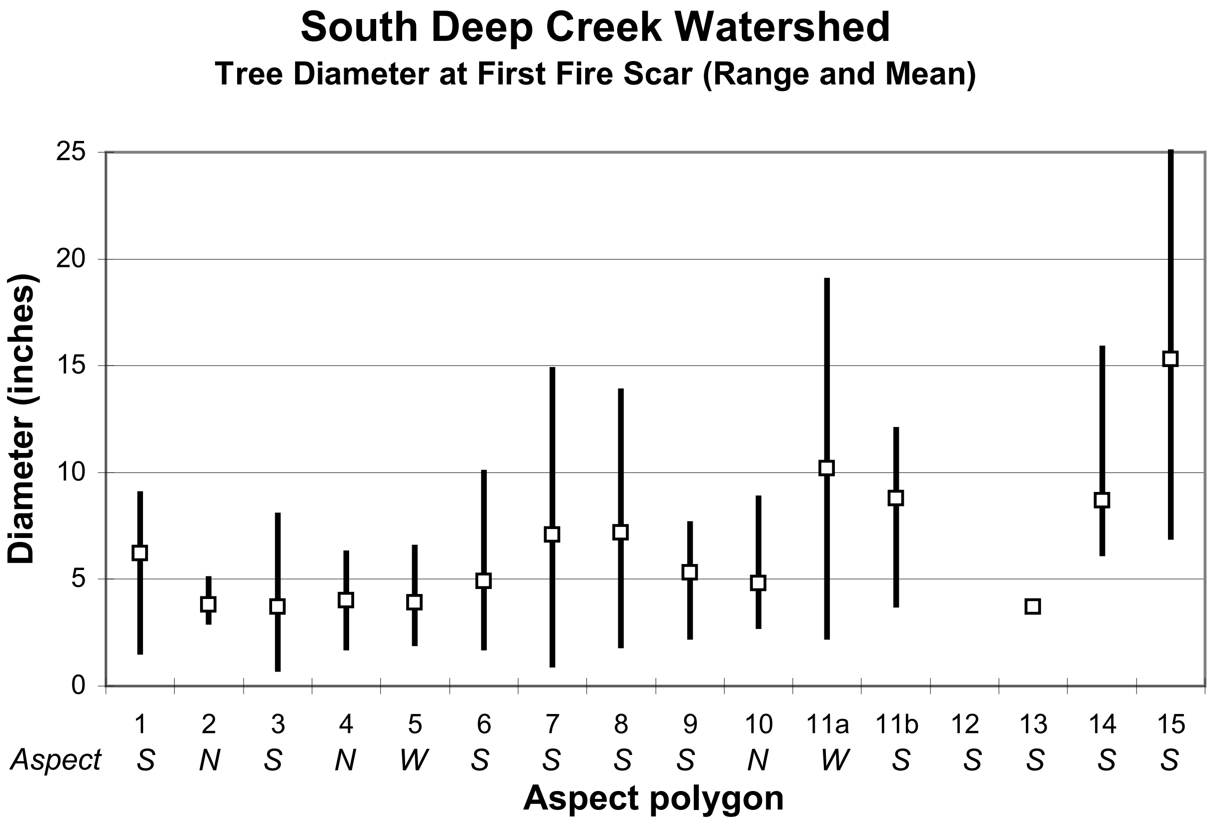

Fig. 6. Mean and range of tree diameters at time of initial scarring.

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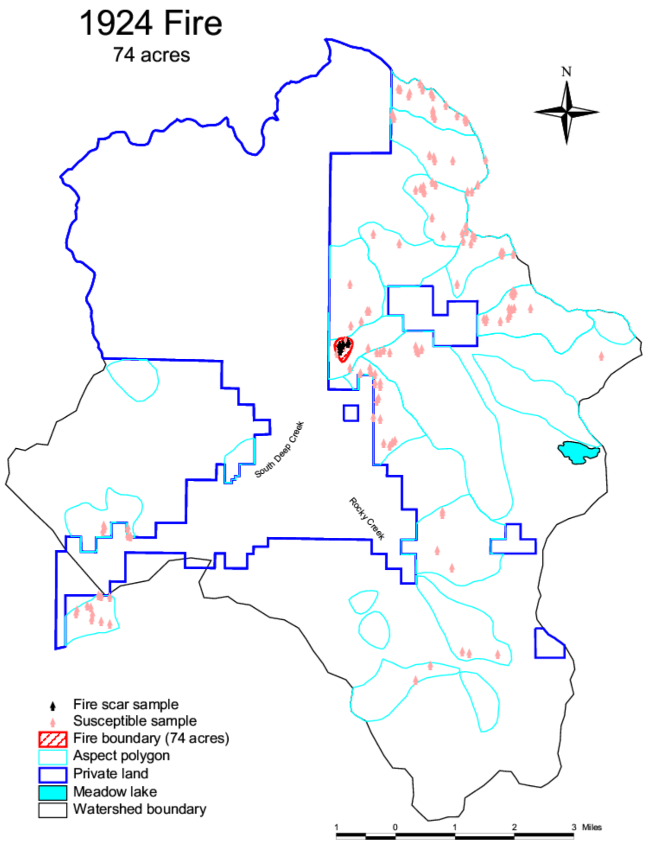
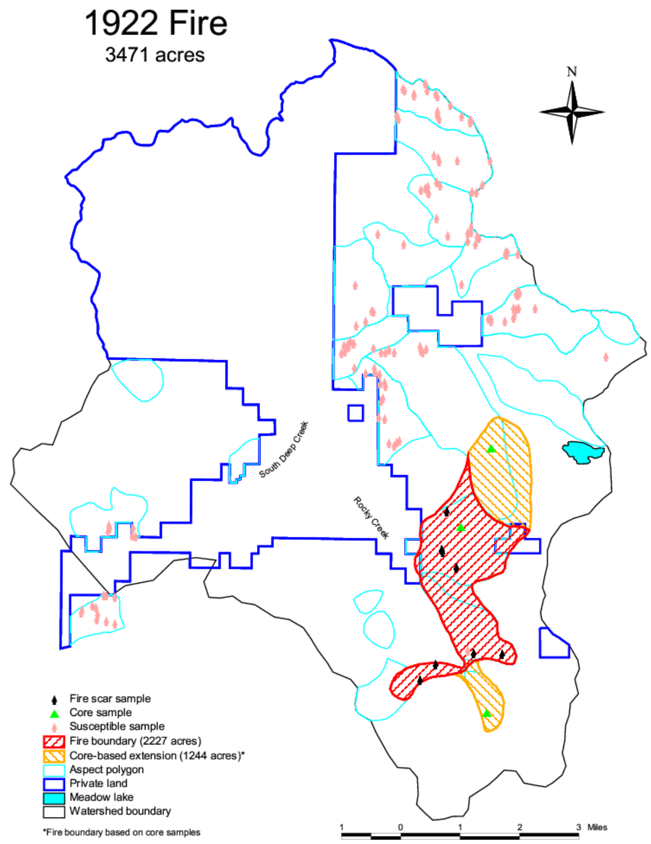
APPENDIX

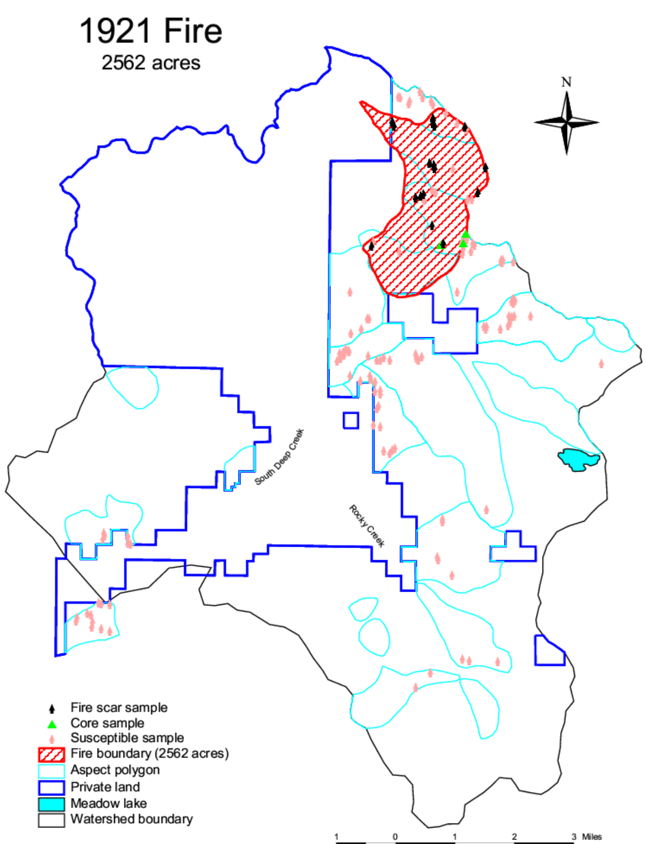
The following maps show fire extent based on the more conservative method described in the report (in red) as well as a less conservative method (additional area added in yellow). Fire size, listed beneath the date, includes the area covered by both red and yellow. The black “trees” show locations of fire scarred material that provide evidence for each fire. The red “trees” are those that would have been susceptible to scarring, having already been scarred by a previous fire. Green triangles show locations of cohort-based data (derived from analyses of increment cores) from which the extended fire boundary was derived.



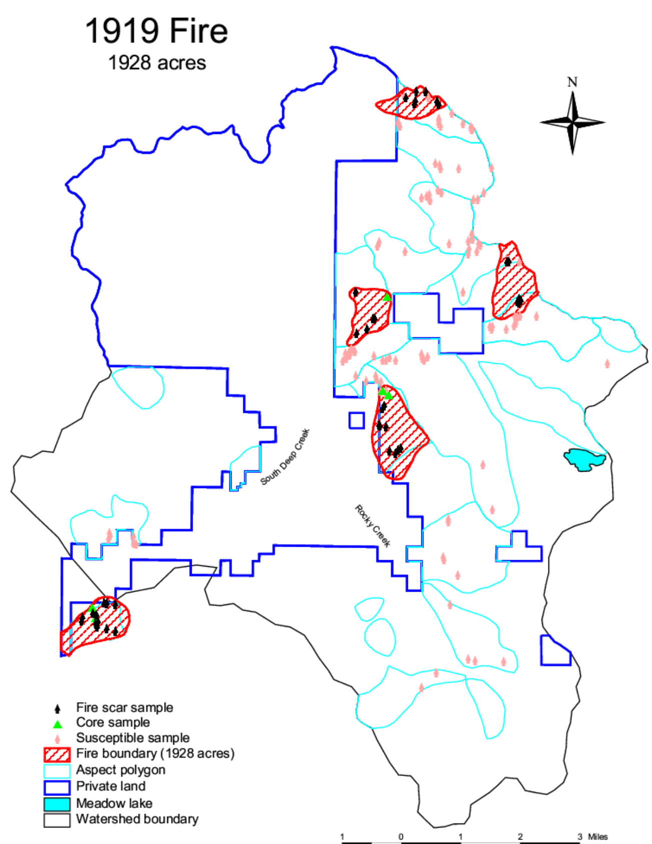
1924 Fire
74 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Susceptible sample
Fire boundary (74 acres)
Aspect polygon
Private land
Meadow lake
Watershed boundary
1
0
1
2
3 Miles



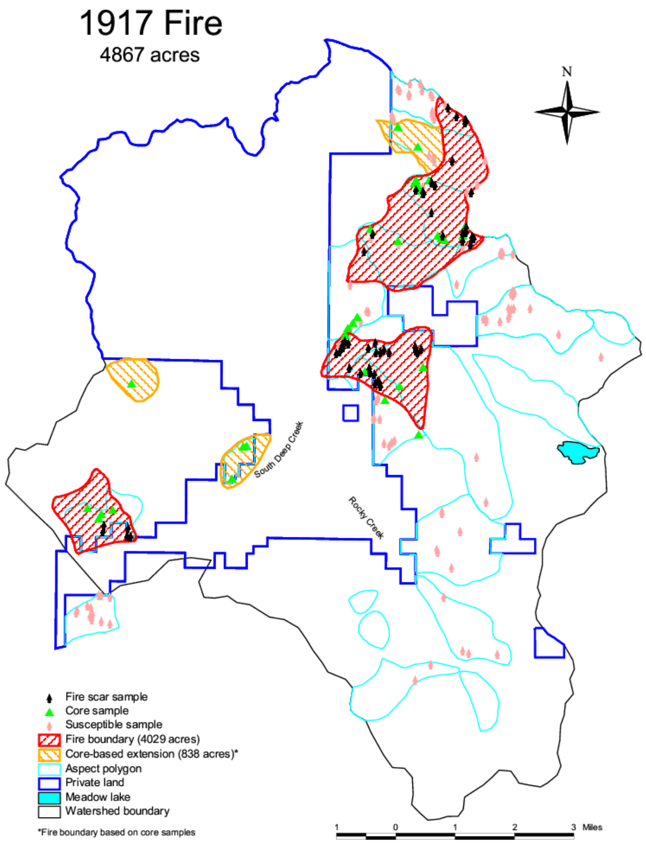
1922 Fire
3471 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (2227 acres)
Core-based extension (1244 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1
0
1
2
3 Miles

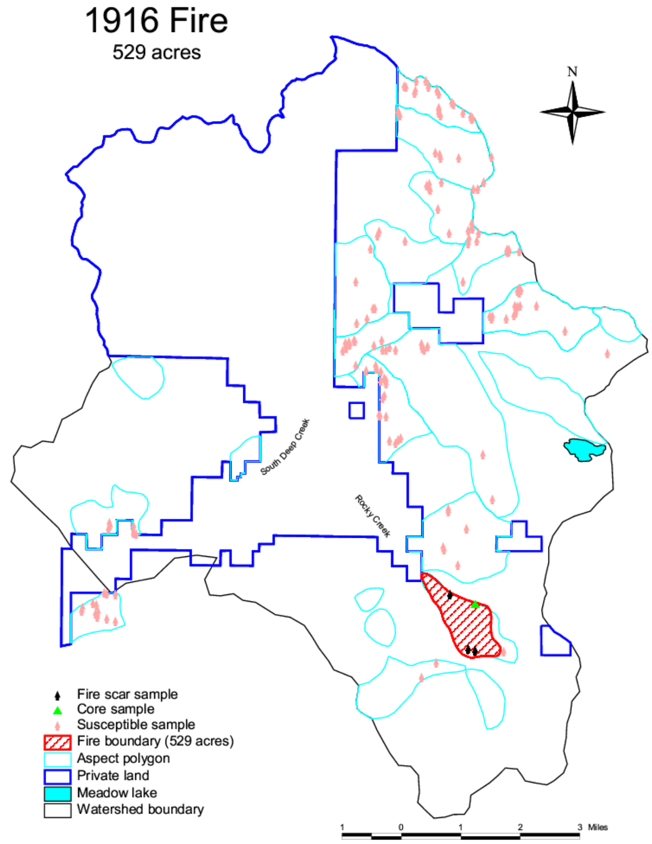


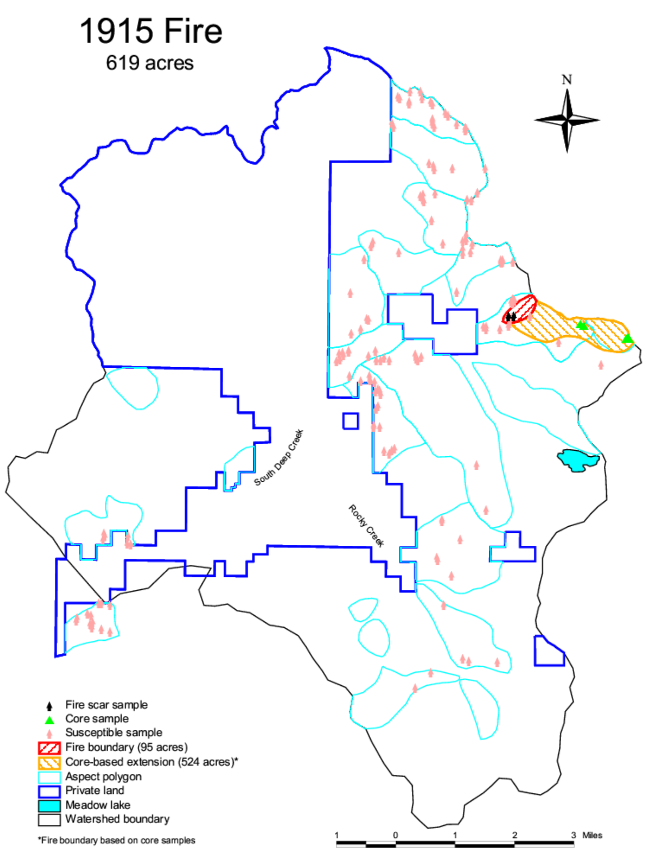
1921 Fire
2562 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (2562 acres)
Aspect polygon
Private land
Meadow lake
Watershed boundary
1
0
1
2
3 Miles

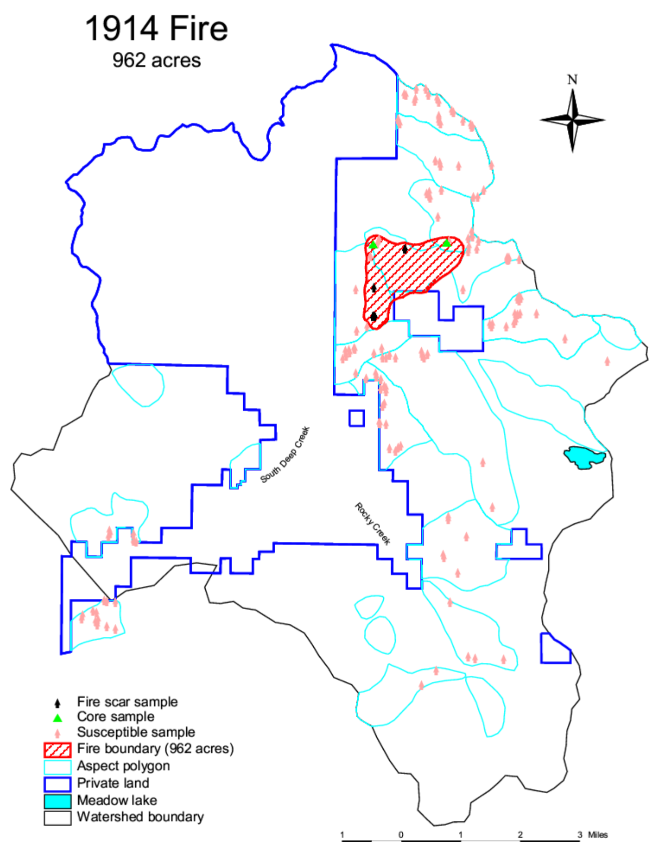


1919 Fire
1928 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (1928 acres)
Aspect polygon
Private land
Meadow lake
Watershed boundary
1
0
1
2
3 Miles

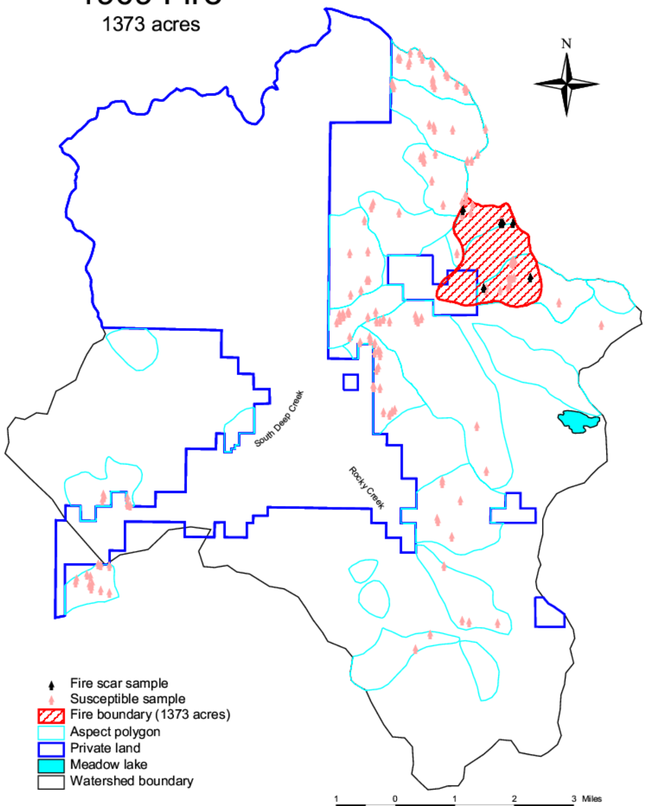

1917 Fire
4867 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (4029 acres)
Core-based extension (838 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1 0 1 2 3 Miles


1916 Fire
529 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (529 acres)
Aspect polygon
Private land
Meadow lake
Watershed boundary
1 0 1 2 3 Miles

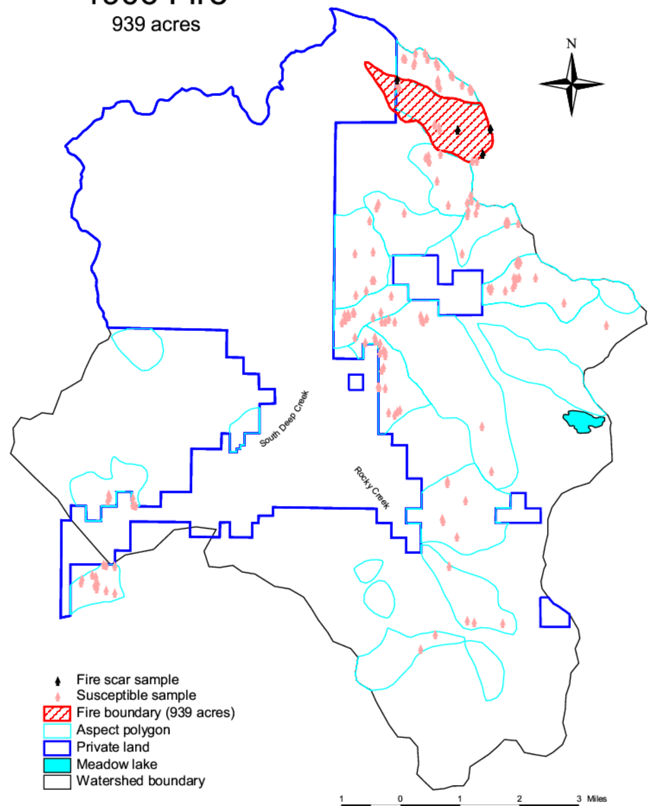

1915 Fire
619 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (95 acres)
Core-based extension (524 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1 0 1 2 3 Miles


1914 Fire
962 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (962 acres)
Aspect polygon
Private land
Meadow lake
Watershed boundary
1 0 1 2 3 Miles

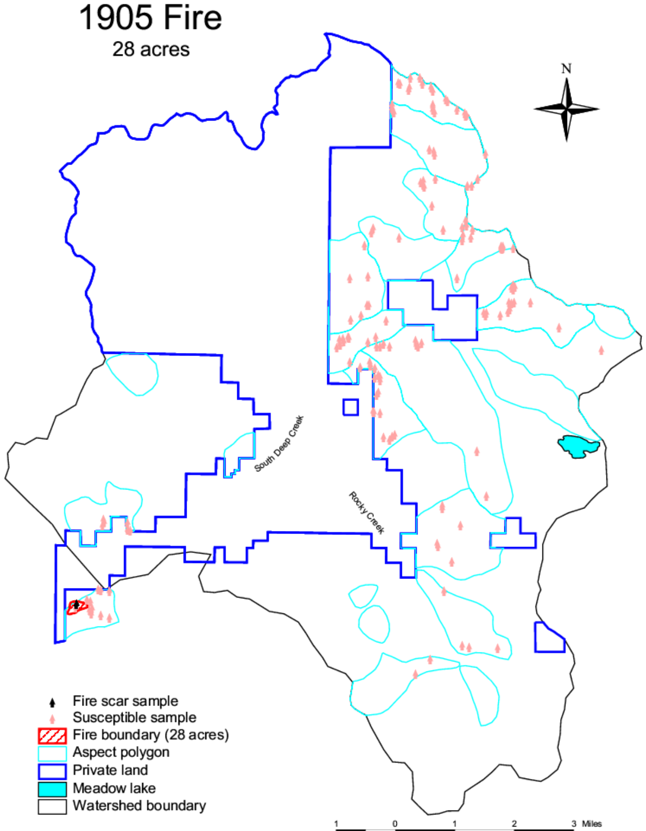
1909 Fire
1373 acres



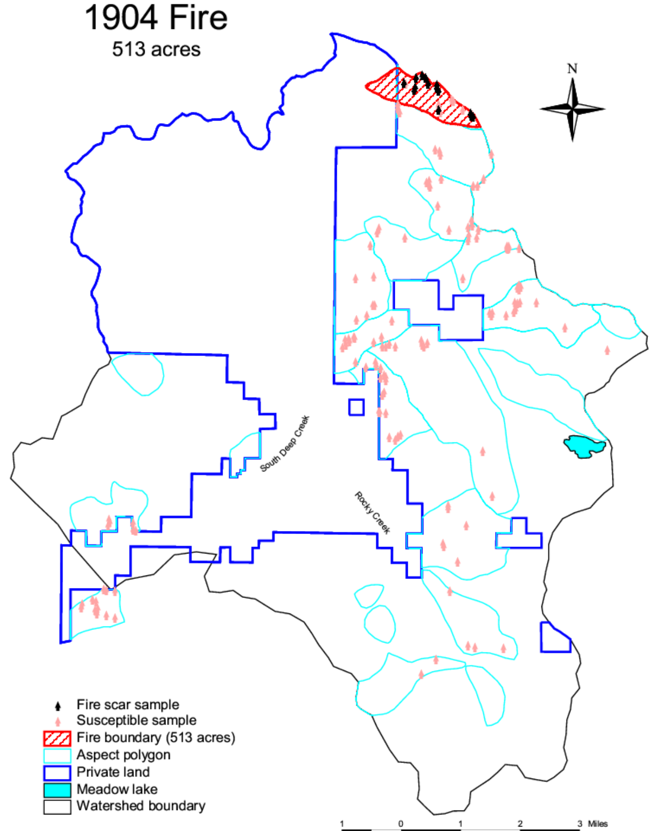
1906 Fire
939 acres



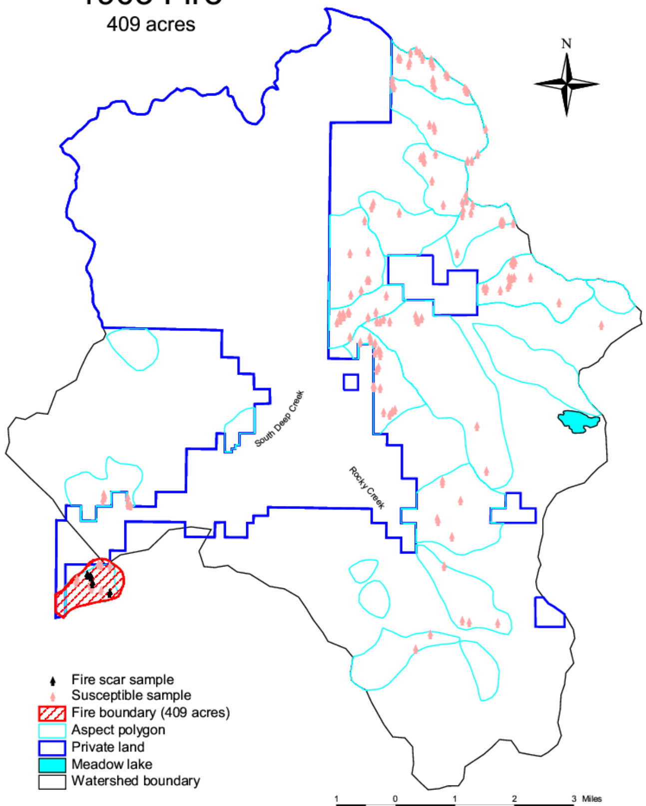
1905 Fire
28 acres



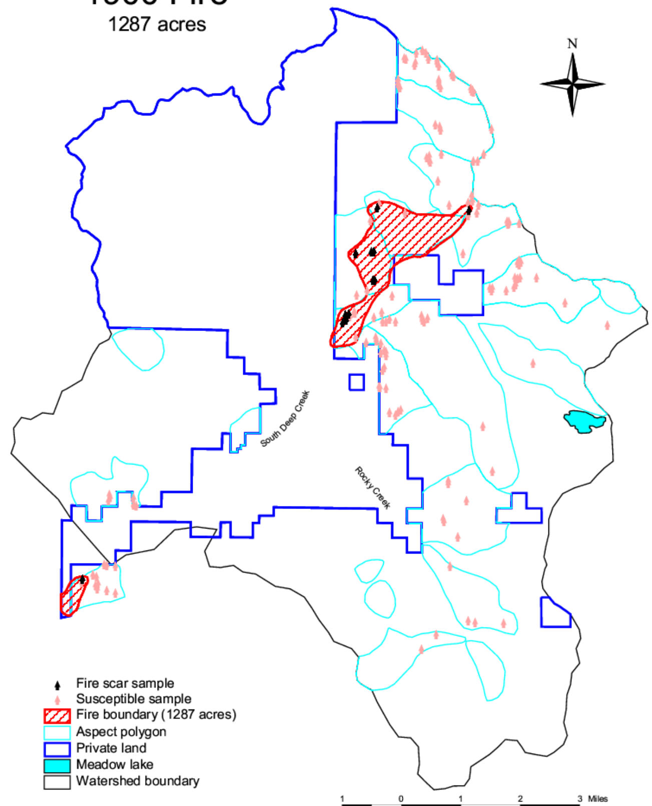
1904 Fire
513 acres



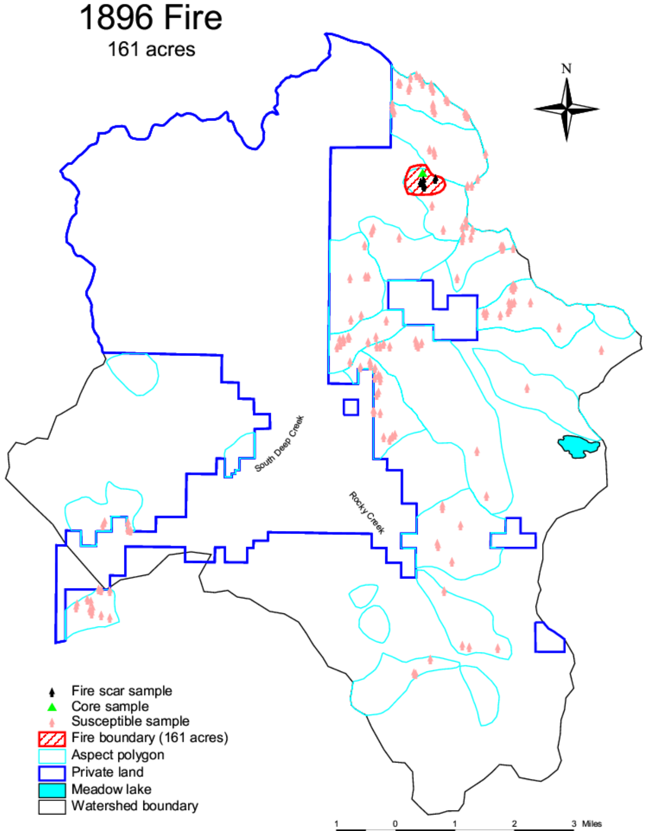
1903 Fire
409 acres



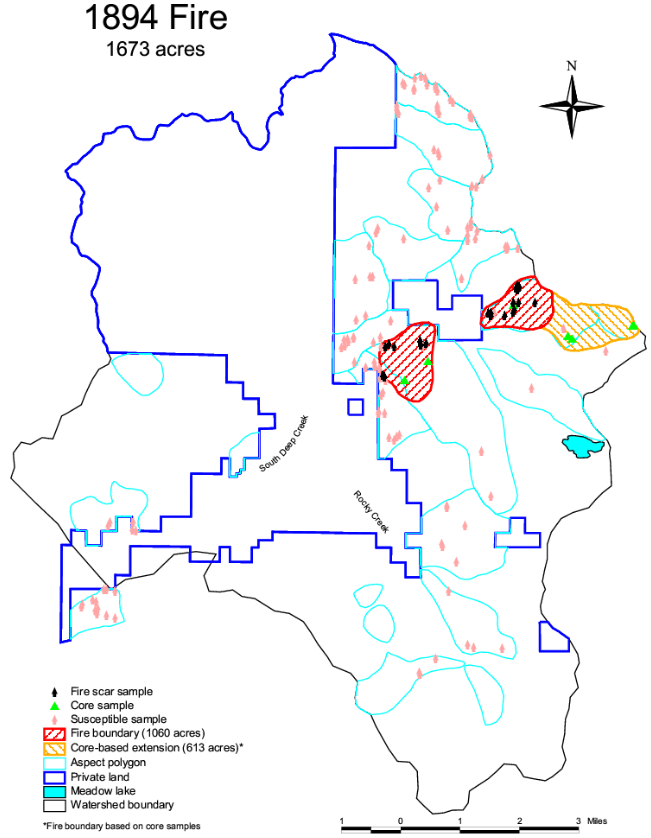
1900 Fire
1287 acres



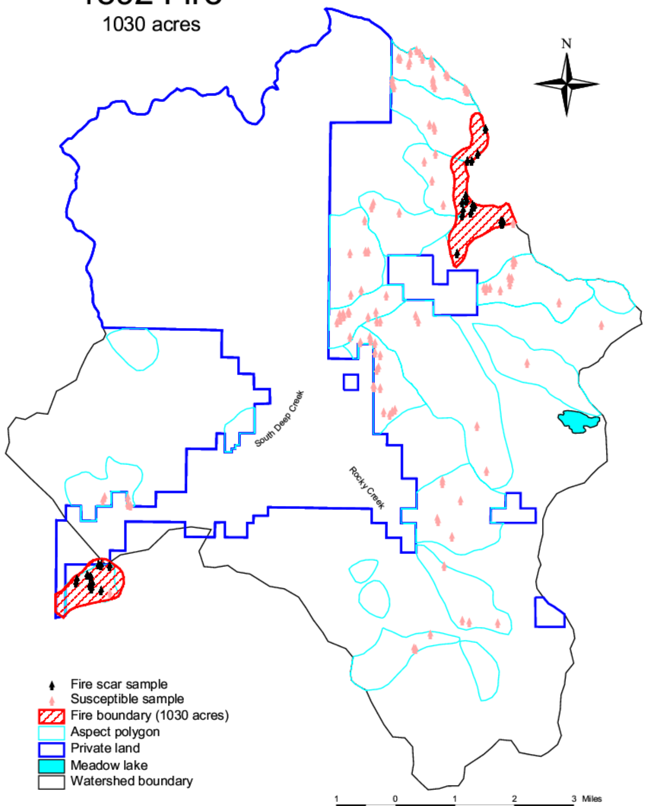
1896 Fire
161 acres



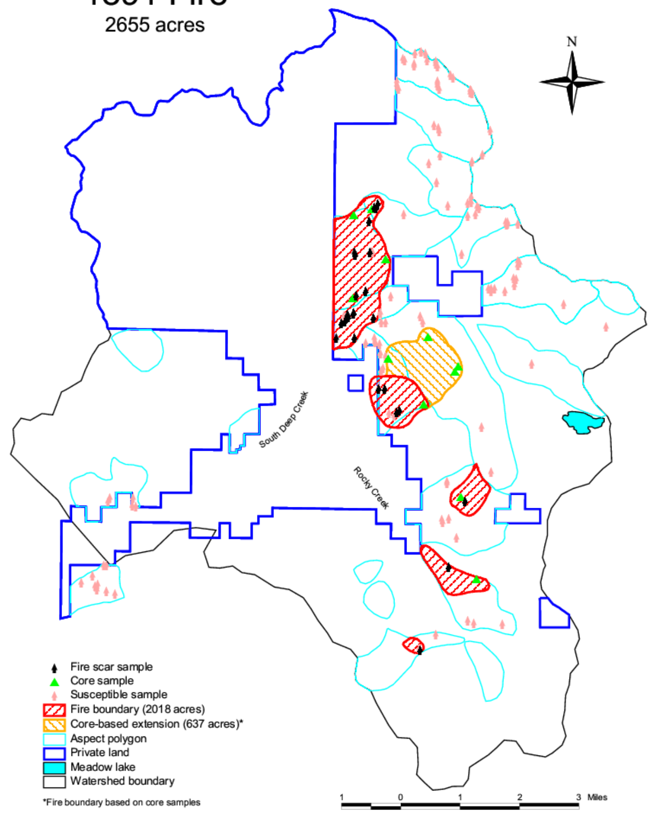
1894 Fire
1673 acres



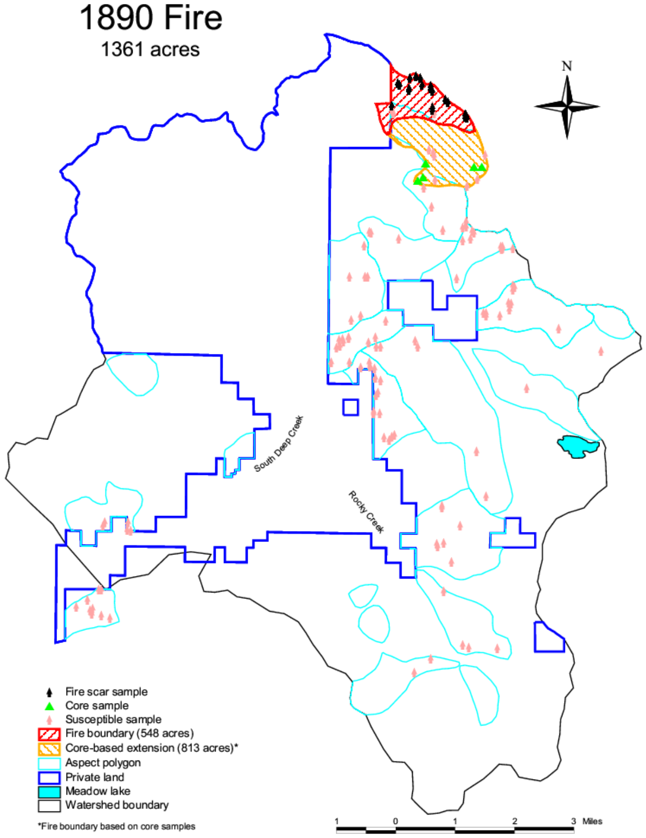
1892 Fire
1030 acres



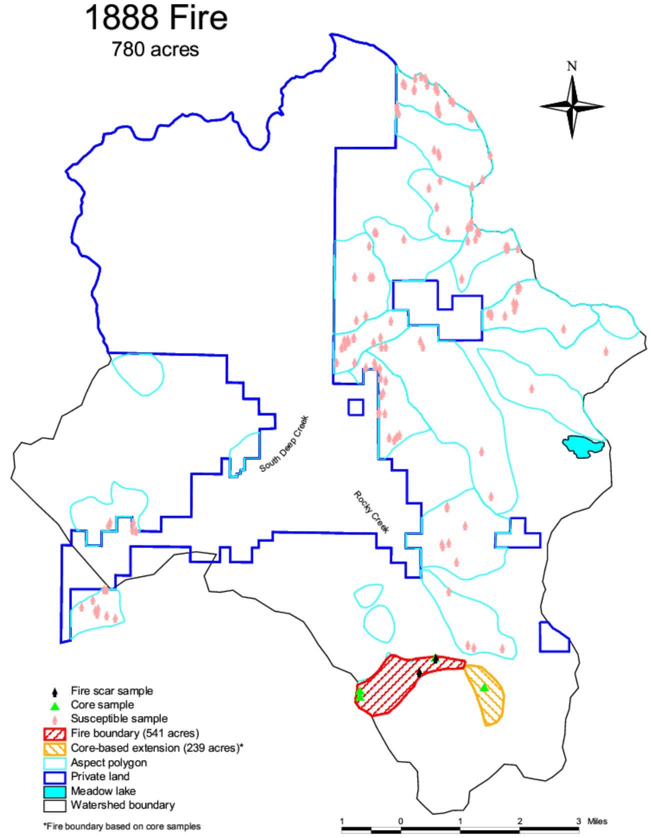
1891 Fire
2655 acres

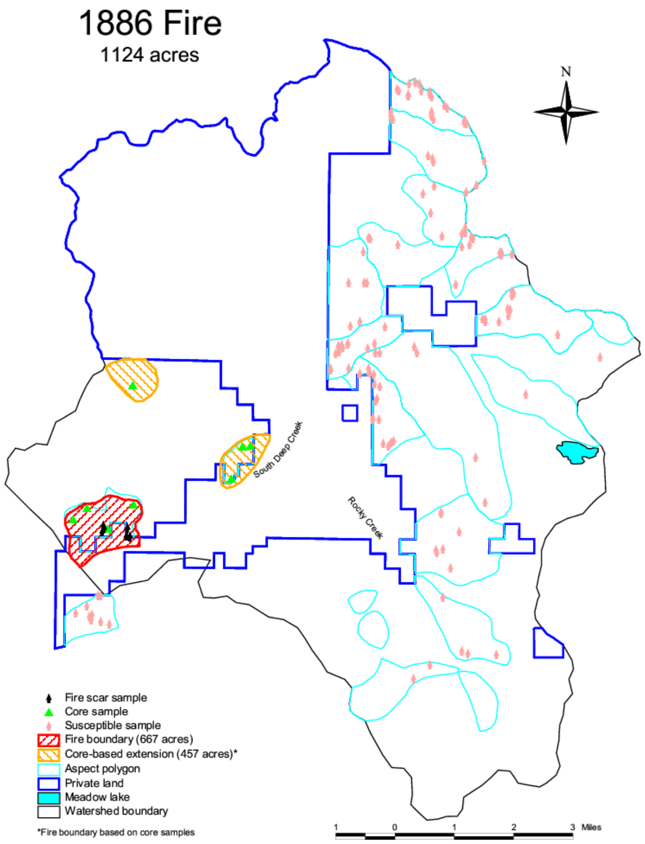


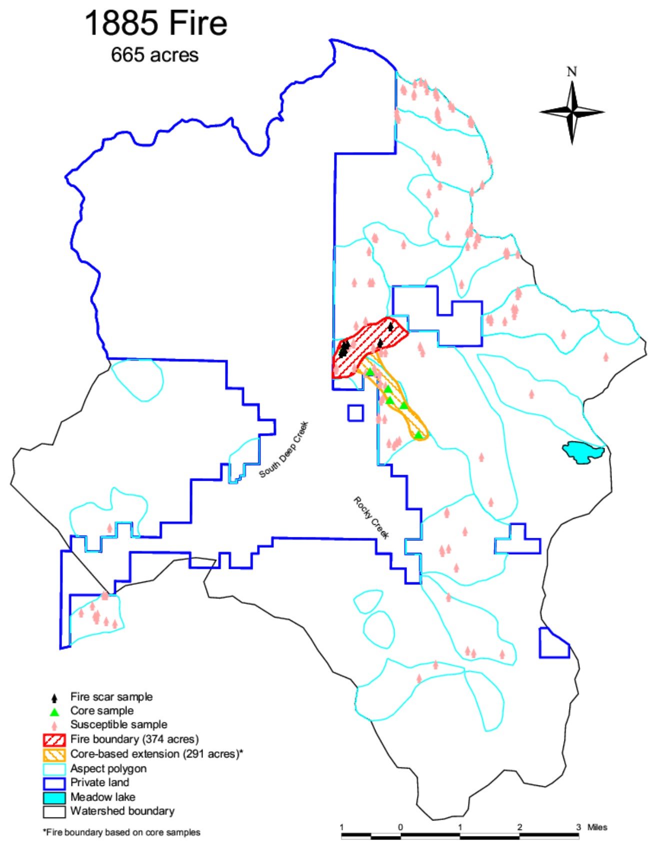
1890 Fire
1361 acres

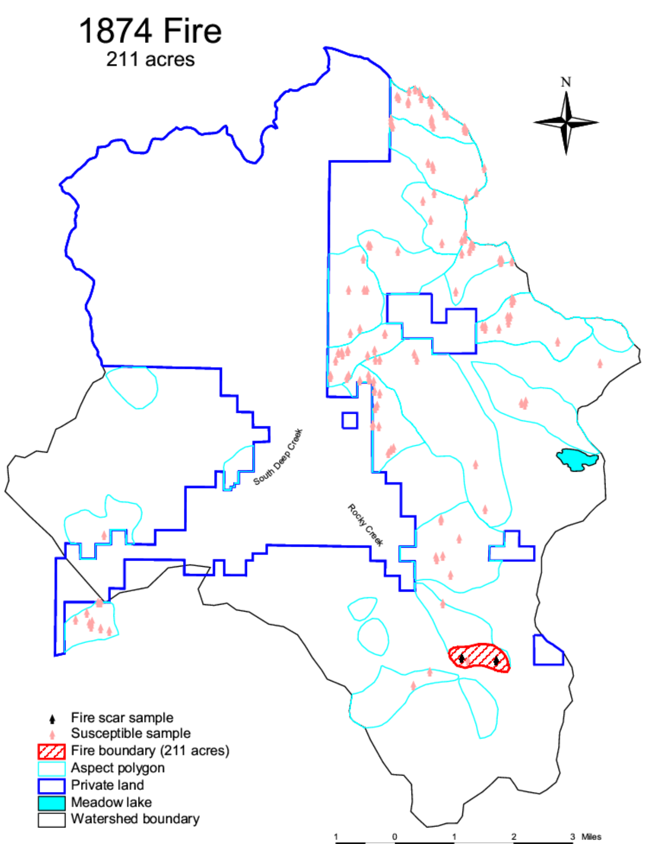


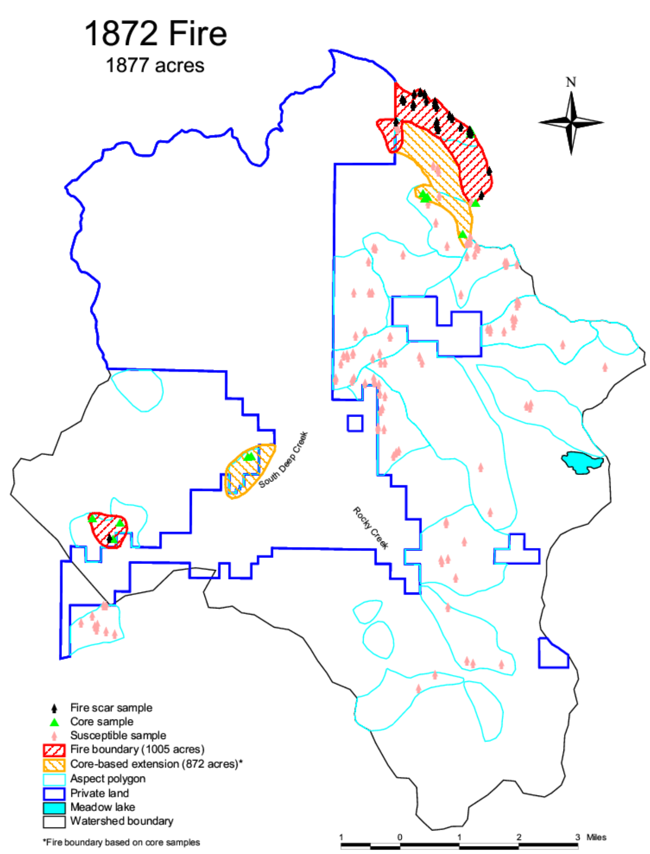
1888 Fire
780 acres



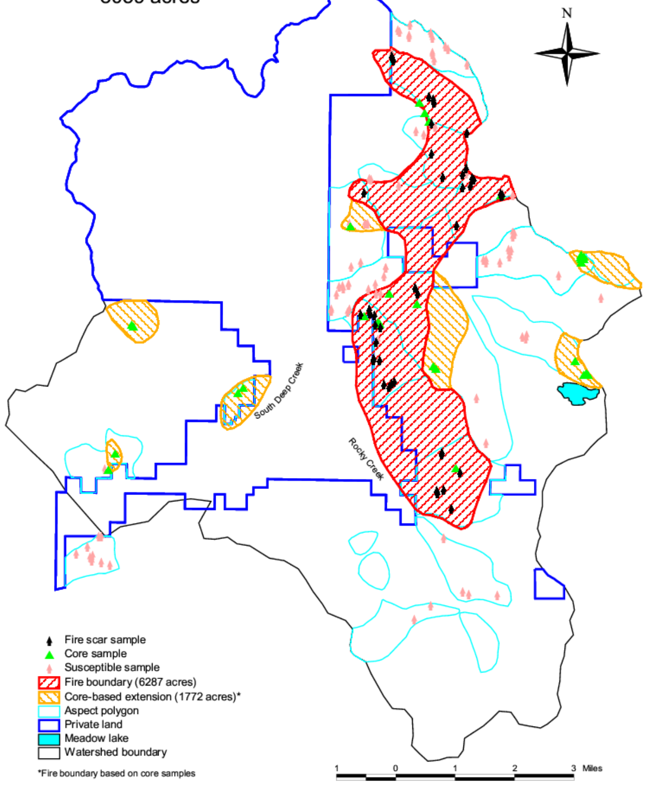

1886 Fire
1124 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (667 acres)
Core-based extension (457 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1 0 1 2 3 Miles


1885 Fire
665 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (374 acres)
Core-based extension (291 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1 0 1 2 3 Miles

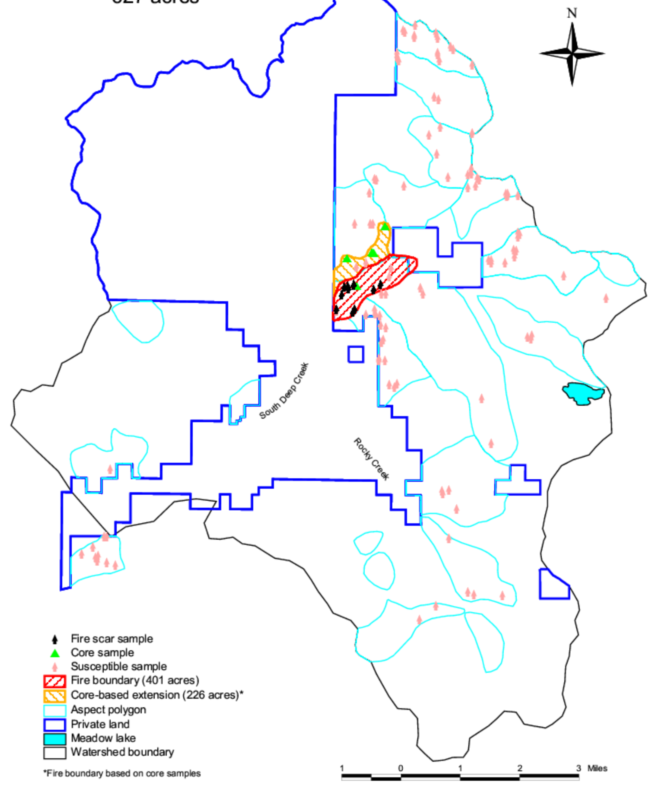

1874 Fire
211 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Susceptible sample
Fire boundary (211 acres)
Aspect polygon
Private land
Meadow lake
Watershed boundary
1 0 1 2 3 Miles


1872 Fire
1877 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (1005 acres)
Core-based extension (872 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1 0 1 2 3 Miles

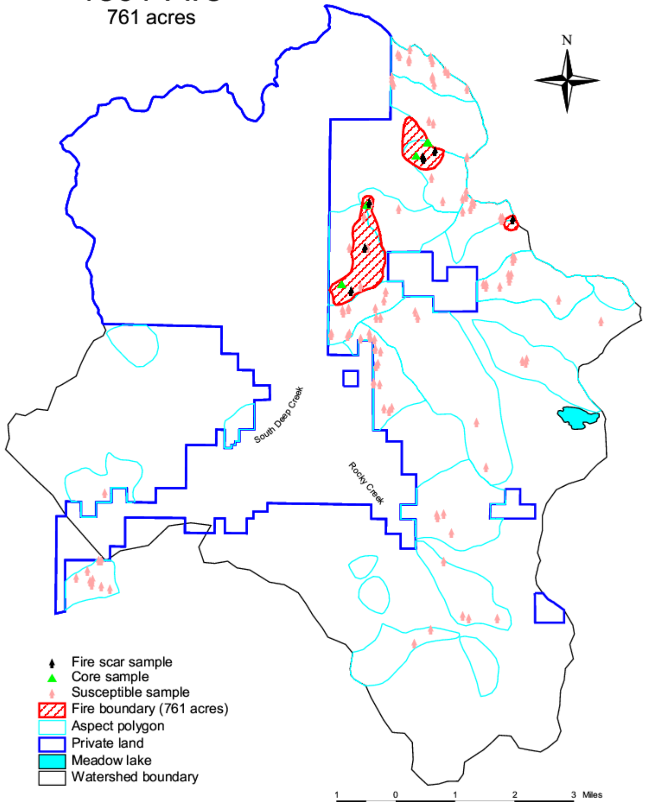
1866 Fire
8059 acres



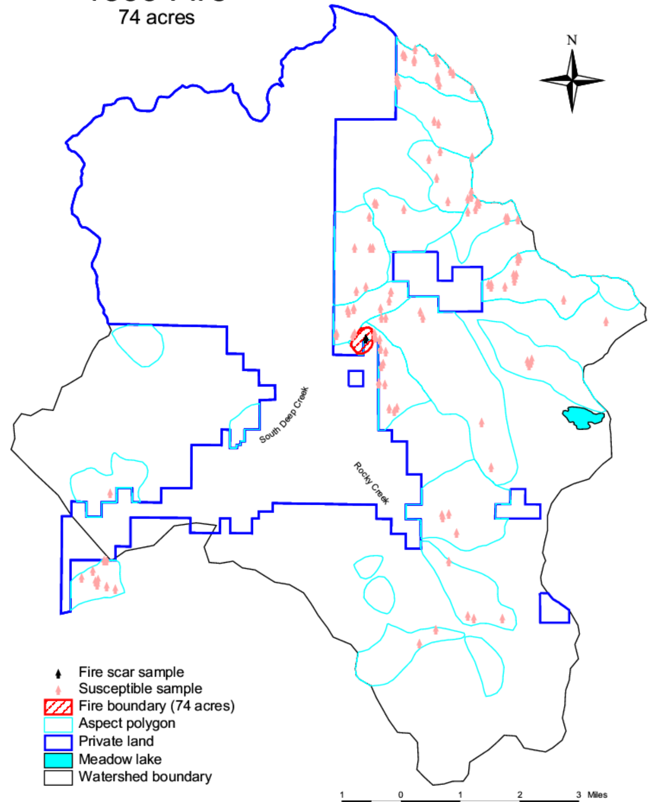
1864 Fire
627 acres

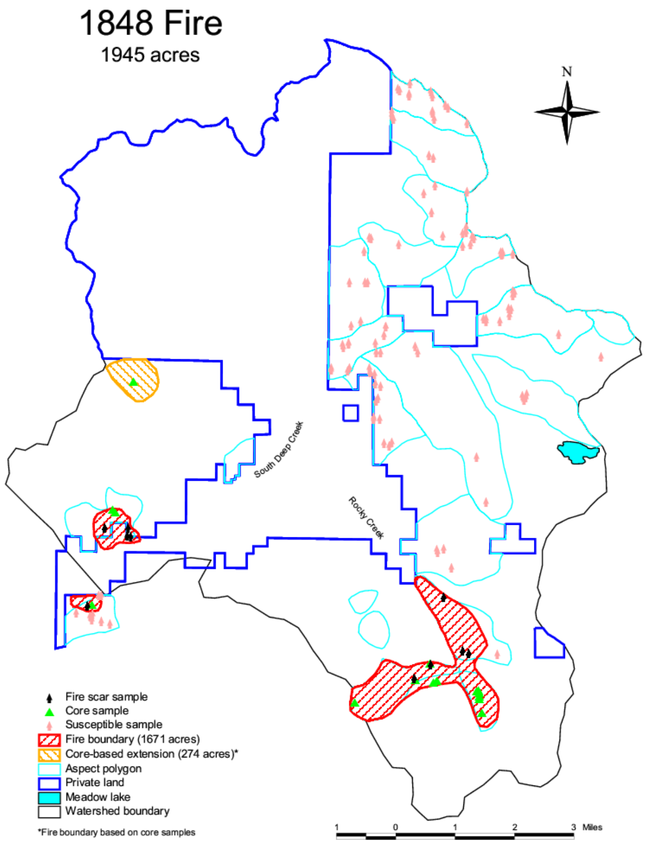


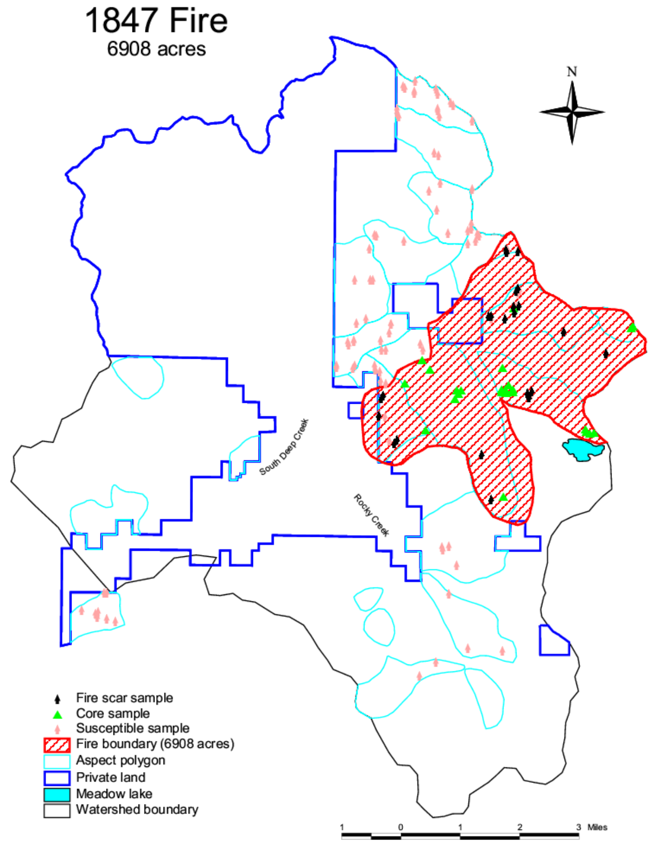
1861 Fire
761 acres

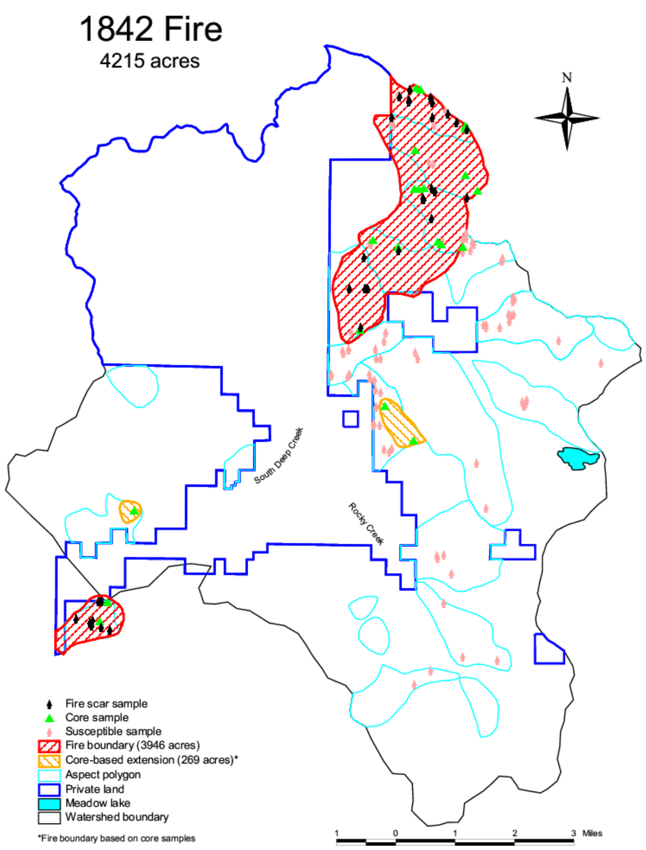


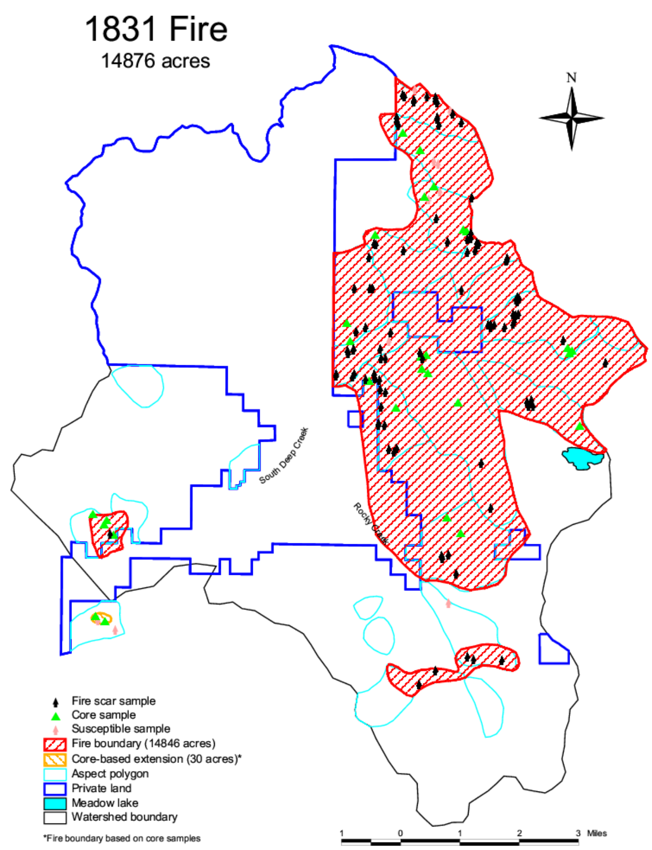
1853 Fire
74 acres



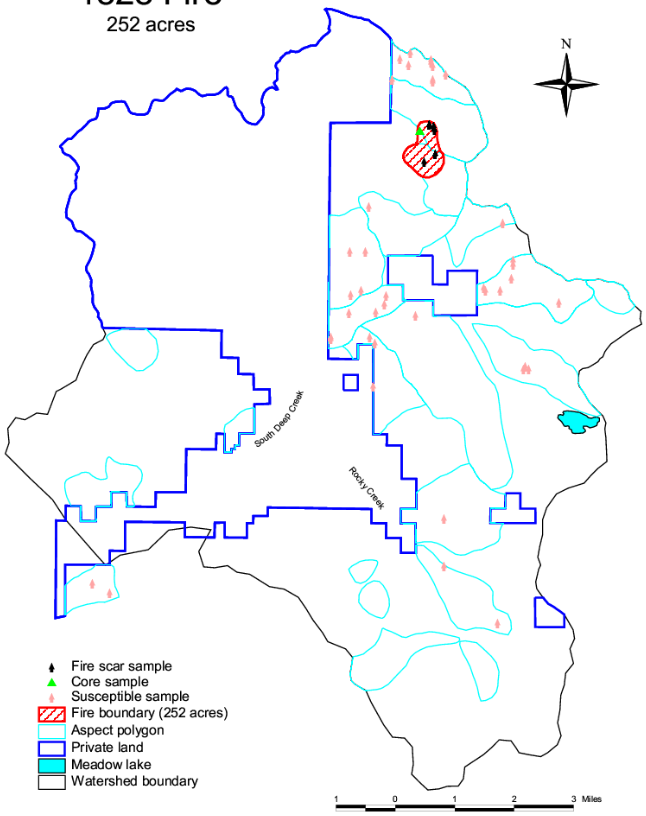

1848 Fire
1945 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (1671 acres)
Core-based extension (274 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1 0 1 2 3 Miles


1847 Fire
6908 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (6908 acres)
Aspect polygon
Private land
Meadow lake
Watershed boundary
1 0 1 2 3 Miles

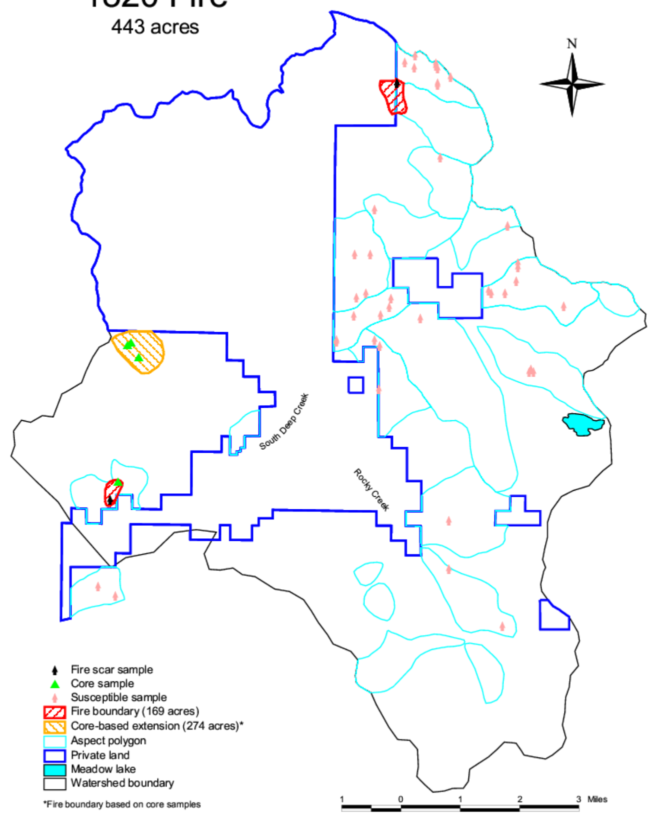

1842 Fire
4215 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (3946 acres)
Core-based extension (269 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1 0 1 2 3 Miles


1831 Fire
14876 acres
N
South Deep Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (14846 acres)
Core-based extension (30 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1 0 1 2 3 Miles

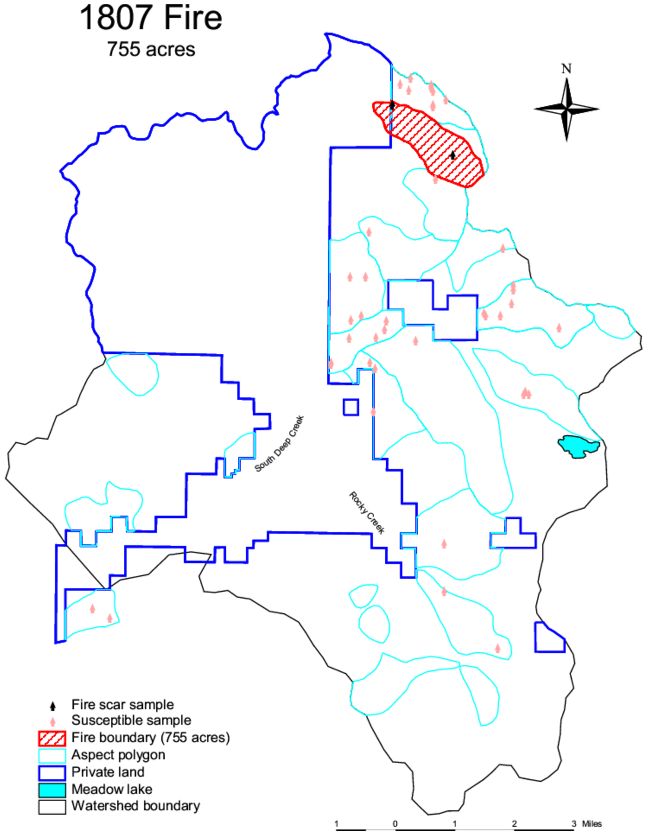
1828 Fire
252 acres



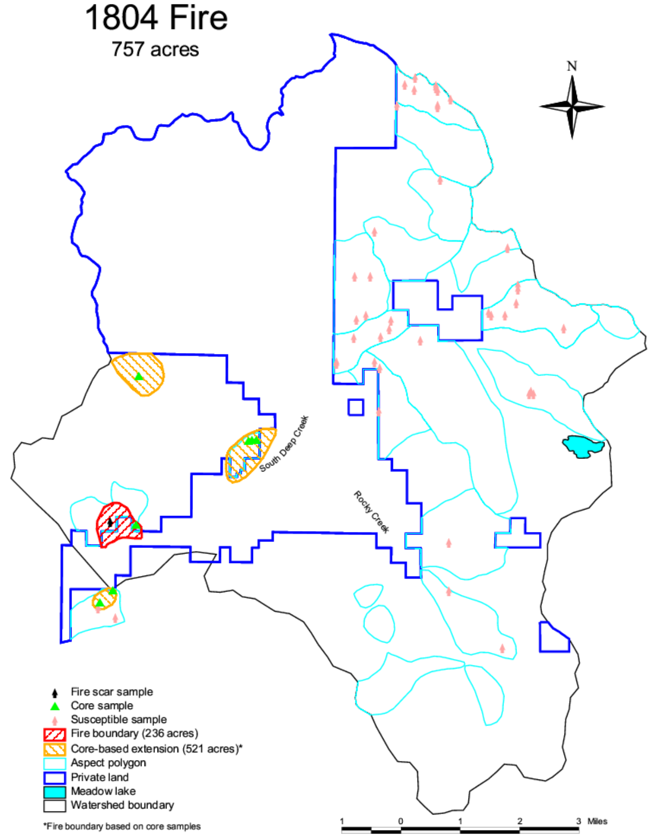
1820 Fire
443 acres



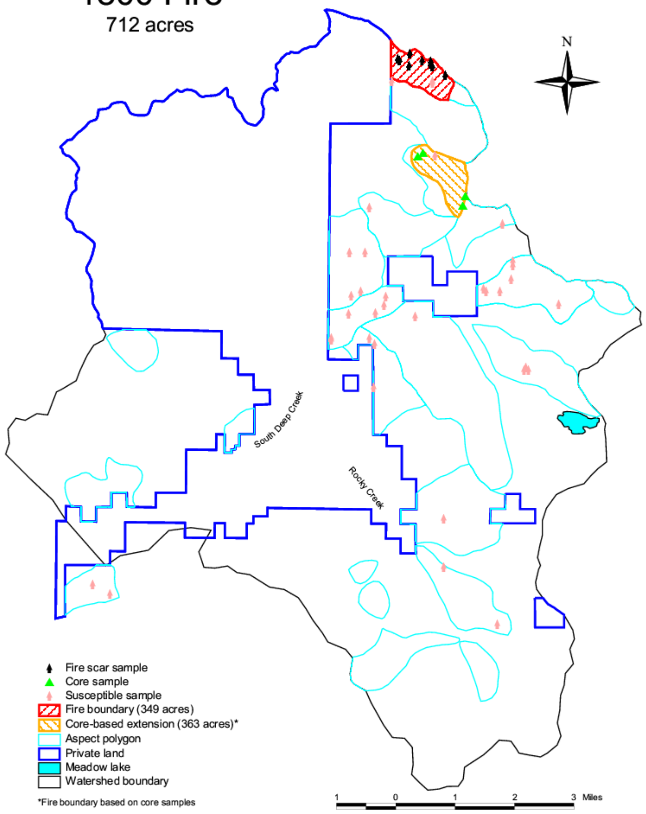
1807 Fire
755 acres



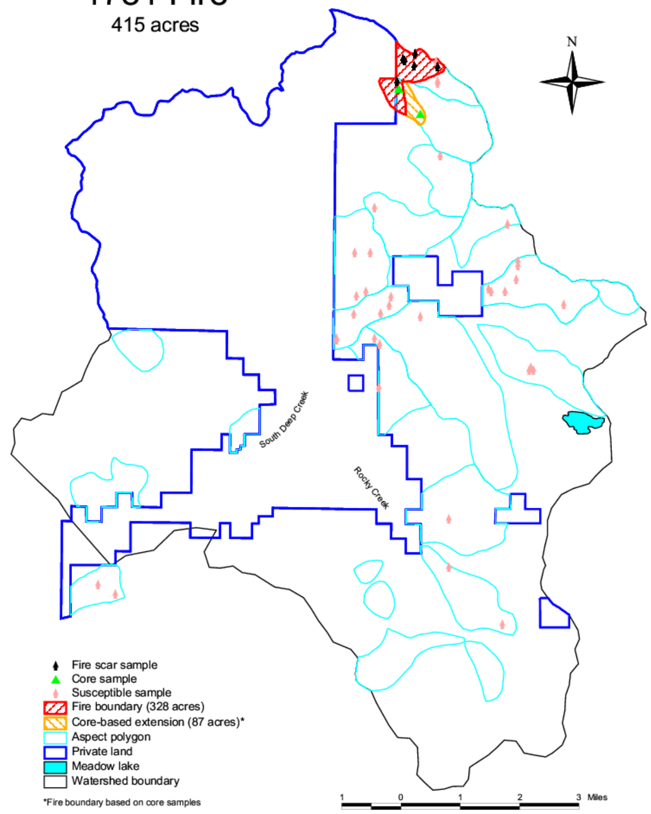
1804 Fire
757 acres



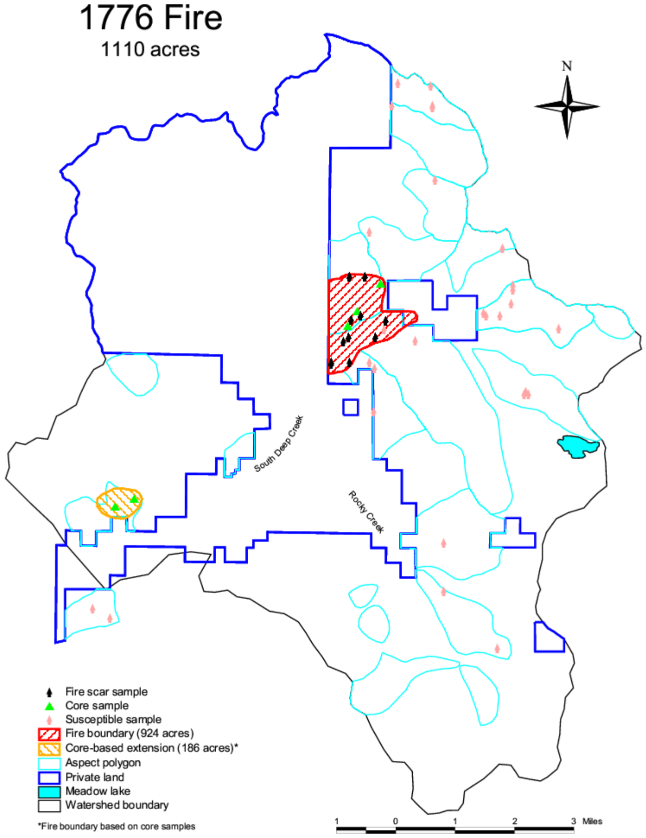
1800 Fire
712 acres



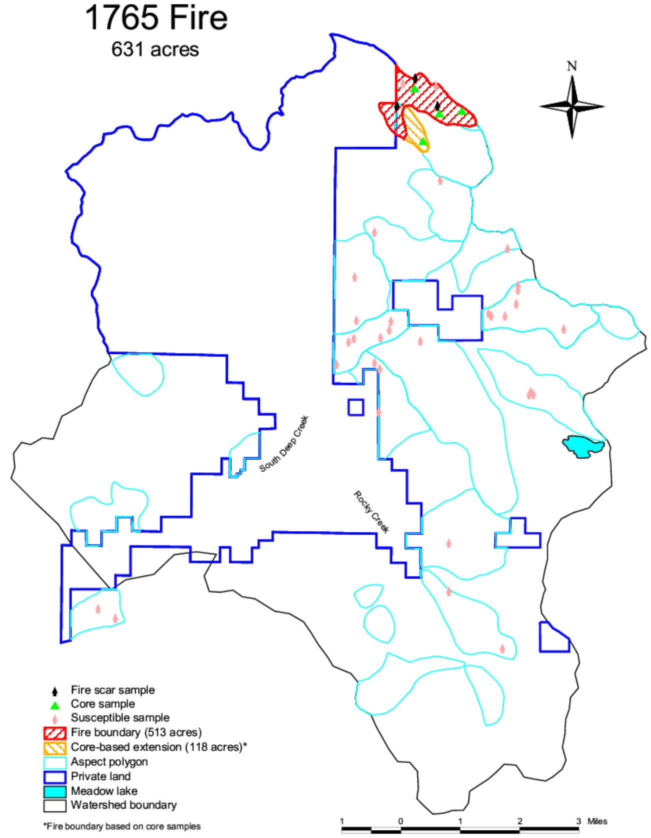
1781 Fire
415 acres



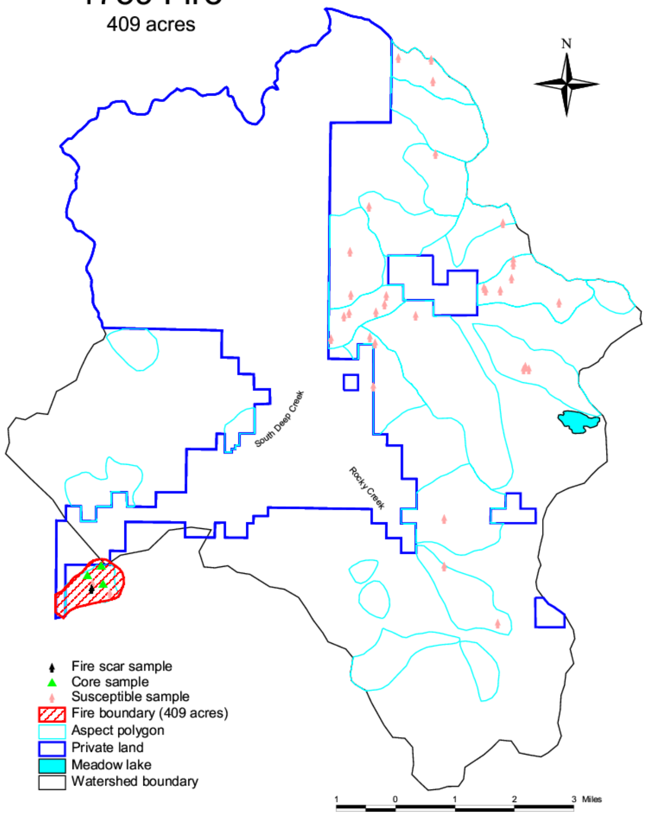
1776 Fire
1110 acres



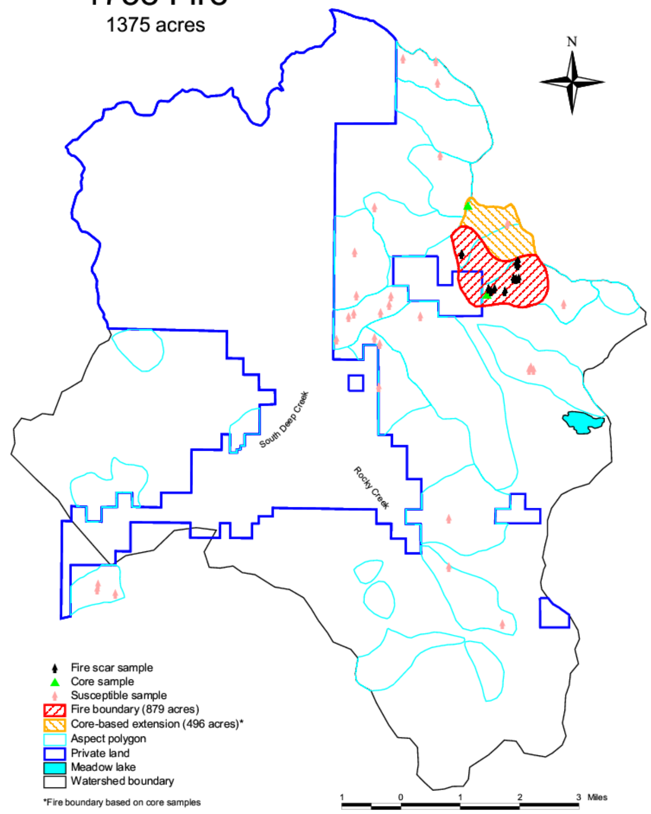
1765 Fire
631 acres



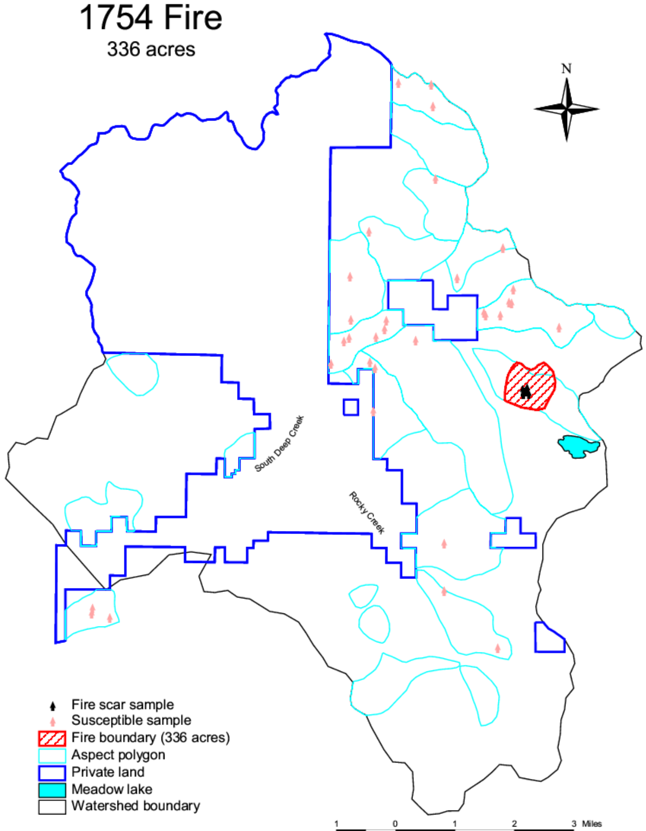
1759 Fire
409 acres



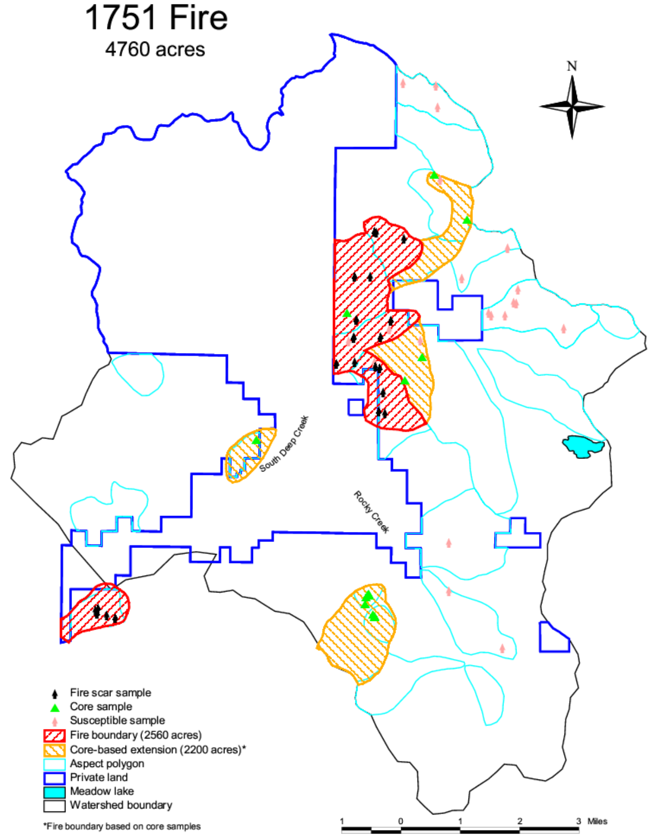
1758 Fire
1375 acres



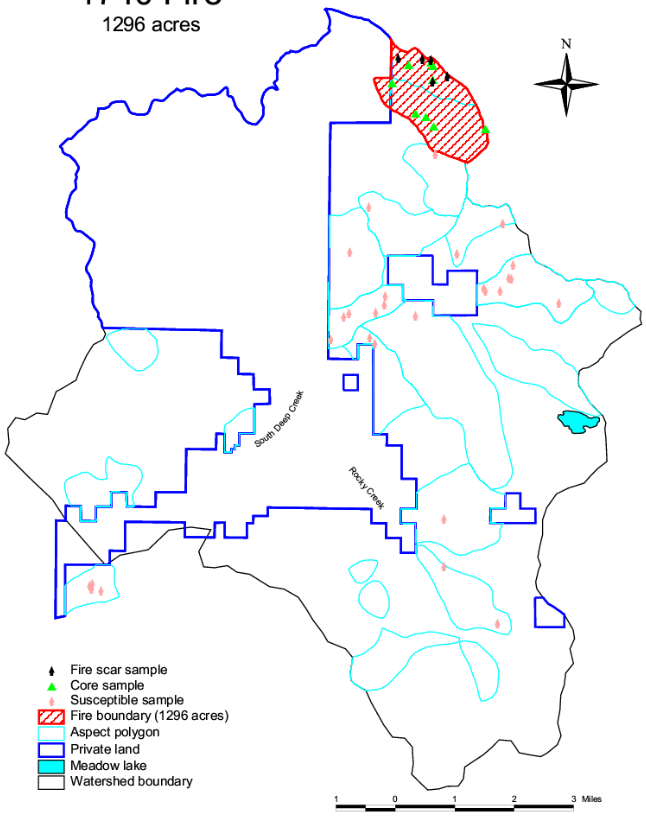
1754 Fire
336 acres



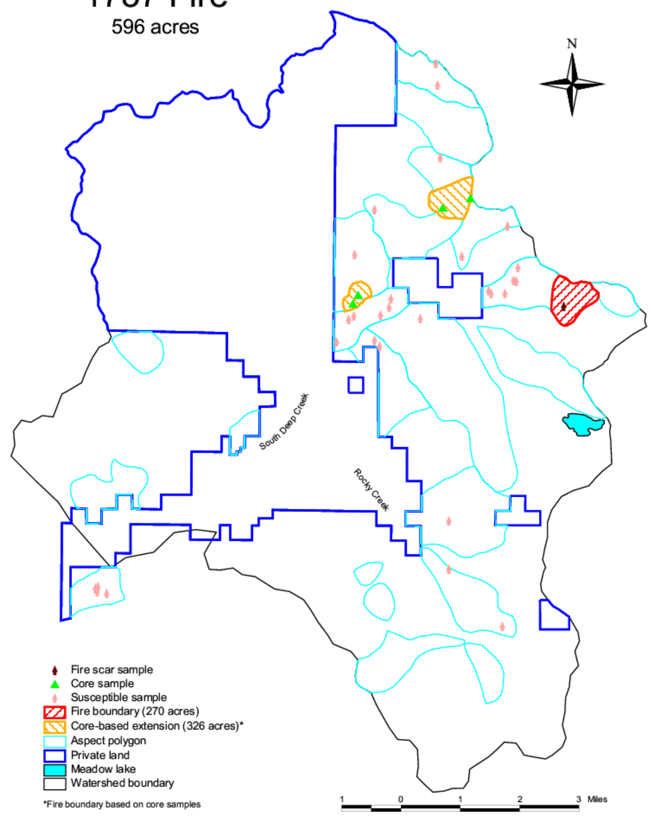
1751 Fire
4760 acres



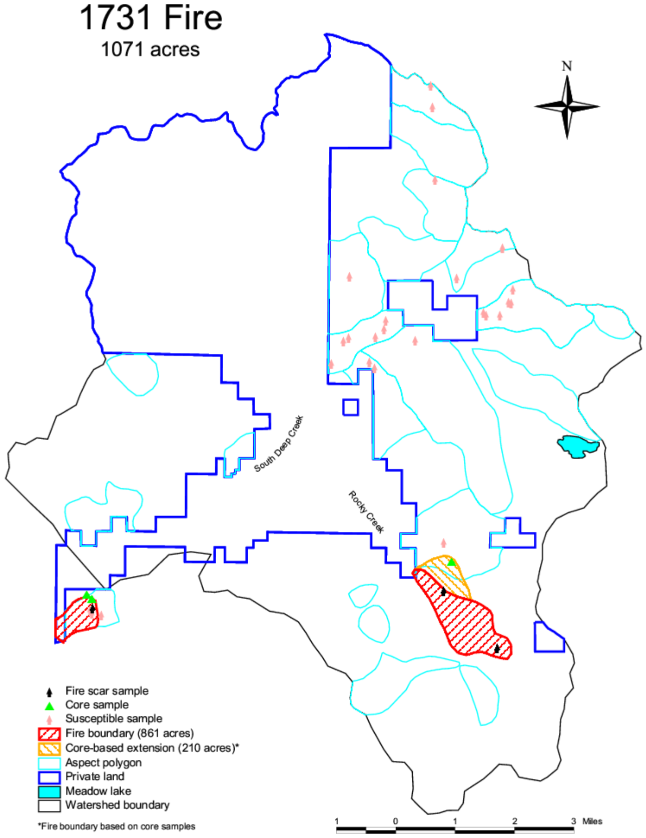
1740 Fire
1296 acres



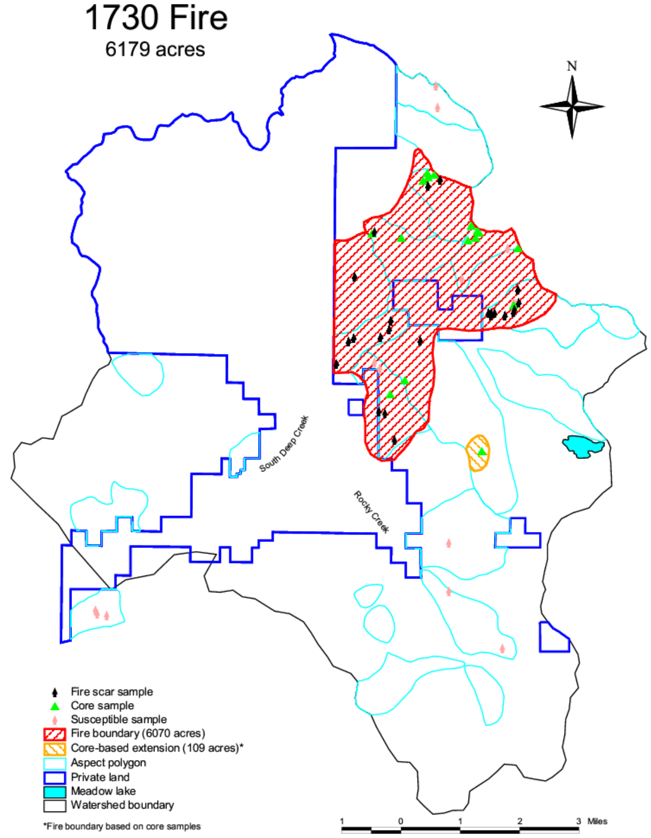
1737 Fire
596 acres



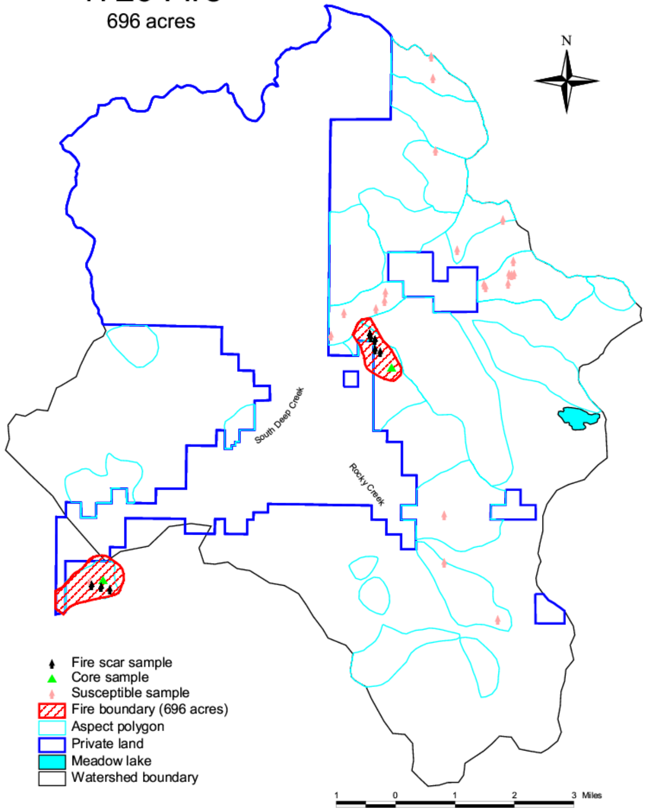
1731 Fire
1071 acres



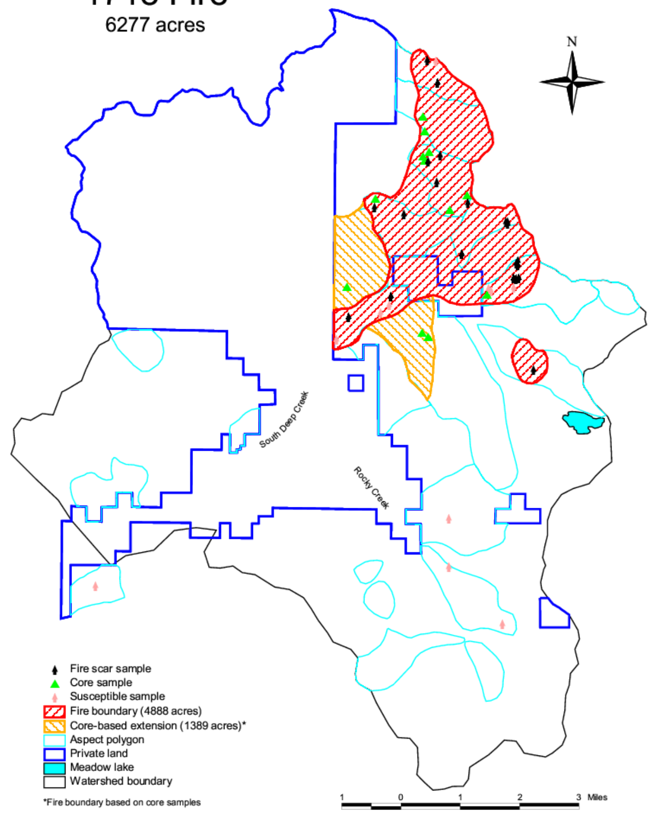
1730 Fire
6179 acres



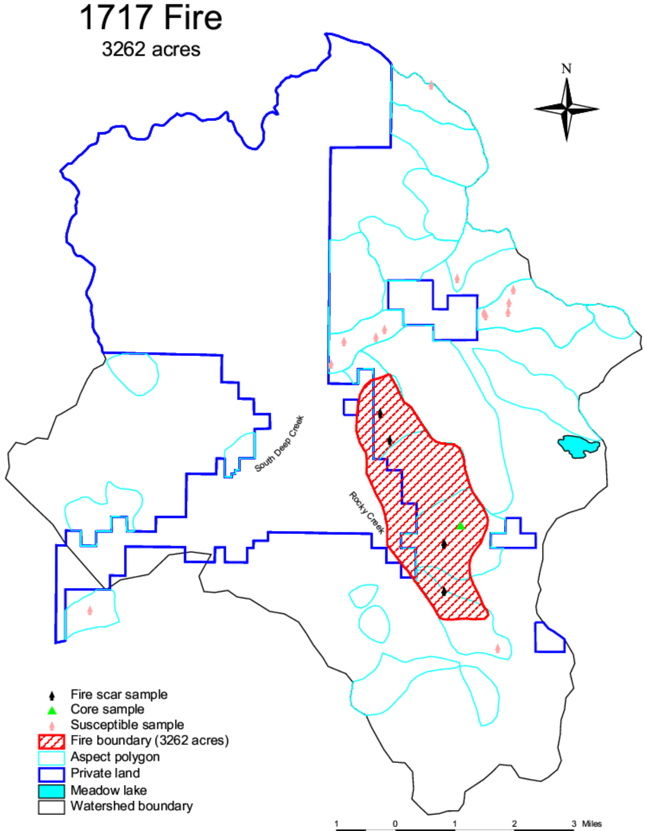
1726 Fire
696 acres



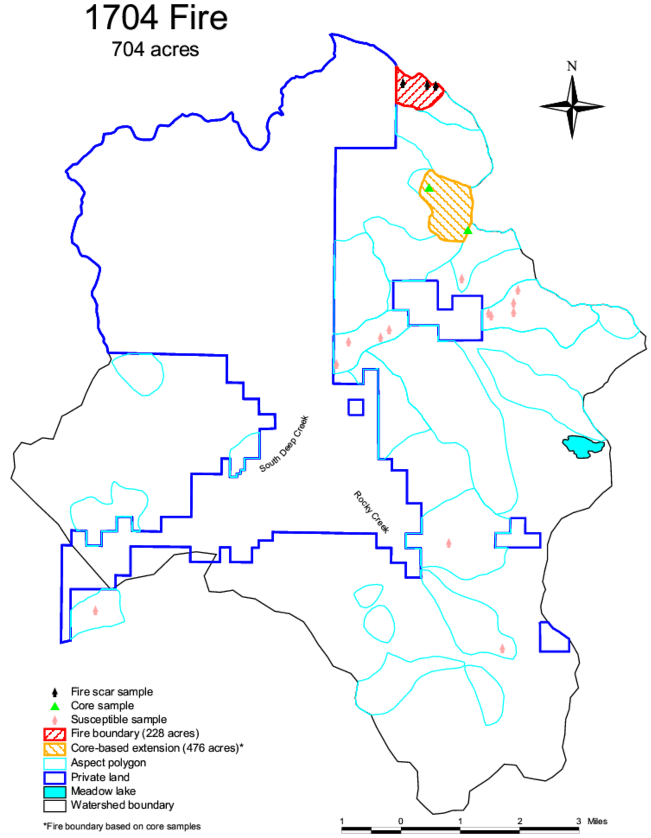
1718 Fire
6277 acres

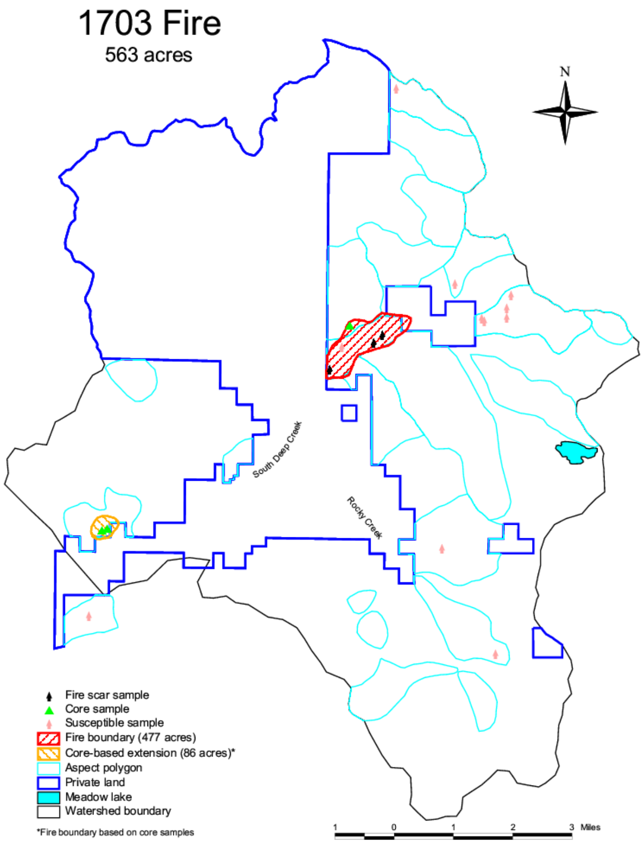


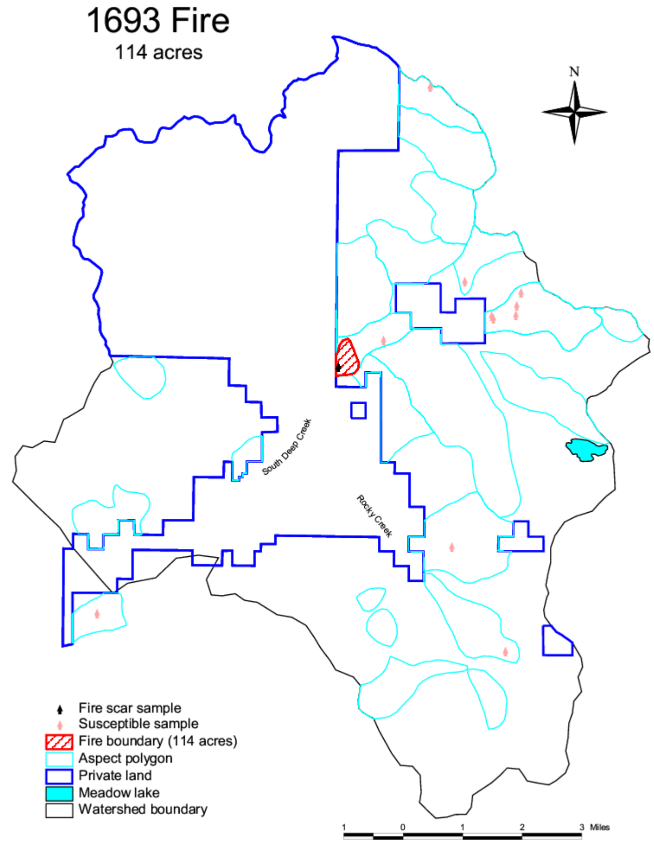
1717 Fire
3262 acres

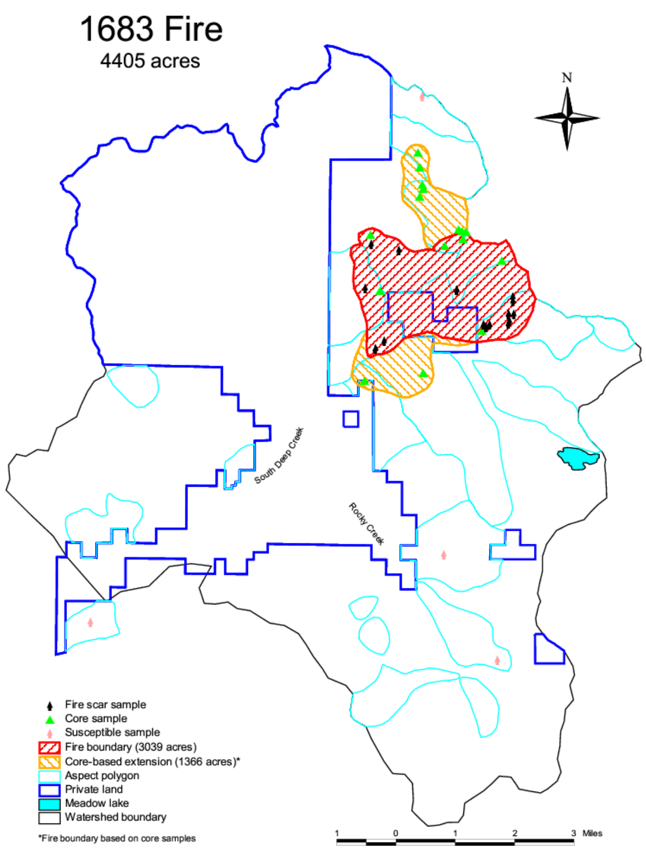


1704 Fire
704 acres




1703 Fire
563 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (477 acres)
Core-based extension (86 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1 0 1 2 3 Miles


1693 Fire
114 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Susceptible sample
Fire boundary (114 acres)
Aspect polygon
Private land
Meadow lake
Watershed boundary
1 0 1 2 3 Miles


1683 Fire
4405 acres
N
South Deep Creek
Rocky Creek
Fire scar sample
Core sample
Susceptible sample
Fire boundary (3039 acres)
Core-based extension (1366 acres)*
Aspect polygon
Private land
Meadow lake
Watershed boundary
*Fire boundary based on core samples
1 0 1 2 3 Miles